REMARKS

Claims 1 and 3-20 are pending in the application. Claims 1 and 4 have been amended to incorporate the subject matter of claim 2, which is canceled without prejudice. Claim 6 has been amended to overcome the rejection under 35 USC 112, second paragraph, in the manner suggested by the Examiner. Claims 3 and 5 have been amended to provide proper antecedence. New claims 18-20 have been added by the present amendment. The amendments are fully supported by the specification as originally filed.

Claims 1 and 2 were rejected under 35 USC 102(e) as being anticipated by U.S. Patent 6,134,058 to Mohri et al. (hereinafter "Mohri"). Claims 1-6 were rejected under 35 USC 103(a) as being unpatentable over U.S. Patent 6,362,927 to Hori in view of Mohri. These rejections are respectfully traversed.

U.S. Patent 6,362,927 to Hori is **not** prior art to the subject application. Attached is an English-language translation of Japanese Application 2000-178428, filed on June 14, 2000, from which priority is claimed. The filing date of this priority document antedates the effective date of U.S. Patent 6,362,927 to Hori, which was filed on August 31, 2000. Applicants' claimed invention is fully described and enabled by Japanese Application 2000-178428. Therefore, Applicants have perfected their priority claim in Japanese Application 2000-178428, and the Hori reference is **not** prior art to the subject application (see MPEP 706.02(b)).

Regarding the rejection of claims 1 and 2, Mohri does not teach or suggest a tilt correction method or an objective lens driving device including a plurality of elastic supporting members each having at least one **bent portion**, where tilt of a movable portion is corrected by varying expansion/contraction amounts of the bent portions.

Mohri discloses an object lens driving device, including a movable section 150, a suspension holder 8 (referred to as a "fixed portion" in the Office Action), and a plurality of suspension wires 4, each suspension wire 4 having a first end attached to the movable section 150 and a second end attached to a tilt spring 10 (see column 6, lines 7-12). Upon actuation of a

driving force on the movable section 150, the tilt spring 10 is deformed around pivotal axes 10a, which causes fixation section 4A of the suspension wire 4 to be displaced in tension or compression (see FIGS. 3B-3D and column 7, lines 35-50, as cited in the Office Action).

Mohri teaches that "each suspension wire 4 is attached to the tilt spring 10" (column 6, lines 10-11). As shown in FIGS. 3B-3D, the suspension wire 4 in Mohri does **not** include a bent portion, but is attached to a separate element, i.e., the tilt spring 10. Moreover, the tilt spring 10 does not bend in an orthogonal or focus direction. Instead, the tilt spring 10 pivots around pivotal axes 10a (see, e.g., FIG. 3C and 3D). Therefore, the arrangement of each suspension wire 4 attached to the tilt spring 10 in Mohri does not correspond to the "at least one bent portion" of the elastic supporting member, as recited in claim 1.

Even if the fixation section 4A of the suspension wire 4 were somehow considered a "bent portion," it does **not** correct tilt in the manner recited in the Applicants' claimed invention. Instead, Mohri requires the use of a separate element, i.e., the tilt spring 10.

In contrast, according to the Applicants' claimed invention, elastic supporting member 3 includes at least one bent portion 3c bent approximately in the optical axis or focus direction (see, e.g., specification at page 20, lines 7-12). As a result, the elastic supporting member 3 acts to offset tilt, whereby the tilt of movable portion 13 in a tangential direction Ta can be minimized (see specification at page 23, lines 3-7; FIG. 11).

For at least the reasons discussed above, the Mohri reference does not anticipate or otherwise render obvious the Applicants' claimed invention.

It is believed that the claims are in condition for immediate allowance, which action is earnestly solicited.

Applicants believe that additional fees are not required for consideration of the within response. However, if for any reason a fee is required or credit is owed for any excess fee paid, the Commissioner is hereby authorized and requested to charge Deposit Account No. **04-1105**.

Respectfully submitted,

EDWARDS & ANGELL, LLP

Date: September 3, 2004

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DECLARATION

I, Hisato Noda, c/o Fukami Patent Office, of Mitsui Sumitomo Bank Minamimorimachi Building, 1-29, Minamimorimachi 2-chome, Kita-ku, Osaka-shi, Osaka, Japan, declare:

that I know well both the Japanese and English languages;

that to the best of my knowledge and belief the English translation attached hereto is a true and correct translation of Japanese Patent Application No. 2000-178428, filed on June 14, 2000;

that all statements made of my own knowledge are true;

that all statements made on information and belief are believed to be true; and

that the statements are made with the knowledge that willful false statements and the like are punishable by fine or imprisonment, or both, under 18 USC 1001.

Dated: August 13, 2004

Hisato Noda

Hisato Noda

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出願年月日
Date of Application: ２０００年　６月１４日
June 14, 2000

出願番号
Application Number: 特願２０００－１７８４２８
Pat. Appln. No. 2000-178428

出願人
Applicant(s): シャープ株式会社
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２００１年　４月２７日
April 27, 2001

特許庁長官
Commissioner,
Japan Patent Office

及川耕造
Kozo Oikawa

出証番号　出証特２００１－３０３５７２９
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[List of the Accompanying Documents]

[Document]	Specification	1
[Document]	Drawings	1
[Document]	Abstract	1

[Document Name] Specification

[Title of the Invention] Tilt Correction Method of Movable Portion, Tilt Correction Method of Objective Lens for Optical Disk, and Objective Lens Driving Device for Optical Disk

[Scope of Claims for Patent]

[Claim 1] A tilt correction method of a movable portion for correcting tilt of said movable portion caused when said movable portion is moved in a direction orthogonal to a longitudinal direction of an elastic supporting member (hereinafter referred to as an orthogonal direction), said movable portion being connected to a fixed portion by a plurality of elastic supporting members and displaceably arranged in said orthogonal direction, wherein the tilt of said movable portion is corrected by varying expansion/contraction amounts of said plurality of elastic supporting members caused when said movable portion is moved in said orthogonal direction.

[Claim 2] The tilt correction method of the movable portion according to claim 1, wherein each of said plurality of elastic supporting members has at least one bent portion, and the tilt of said movable portion is corrected by varying expansion/contraction amounts of said bent portions of said elastic supporting members when said movable portion is moved.

[Claim 3] A tilt correction method of an objective lens for an optical disk for correcting tilt of a movable portion caused when moved in a focus direction, said movable portion holding said objective lens, a fixed portion, and a plurality of elastic supporting members connecting said movable portion and said fixed portion for elastically supporting said movable portion in a manner displaceable at least in the focus direction are being provided, wherein

said elastic supporting member has at least one bent portion bent approximately in the focus direction, and said bent portions of said elastic supporting members arranged in parallel in the focus direction are adjusted to cause expansion/contraction of said elastic supporting members in a direction offsetting a moment produced from

deflection of said elastic supporting member.

[Claim 4] An objective lens driving device for an optical disk including a movable portion holding the objective lens, a fixed portion, and a plurality of elastic supporting members connecting said movable portion and said fixed portion and elastically supporting said movable portion in a manner displaceable at least in a focus direction, comprising correction control means for correcting tilt of said movable portion caused when moved in the focus direction by adjusting deflections of said elastic supporting members arranged in parallel in the focus direction to cause expansion/contraction of said elastic supporting members in a direction offsetting a moment produced from deflection of said elastic supporting member.

[Claim 5] The objective lens driving device for the optical disk according to claim 4, wherein said elastic supporting member has at least one bent portion bent approximately in the focus direction for adjustment of deflection.

[Claim 6] The objective lens driving device for the optical disk according to claim 4 or 5, wherein two of said elastic supporting members arranged in parallel approximately in the focus direction are symmetric about the center of support in the focus direction.

[Claim 7] The objective lens driving device for the optical disk according to any of claims 4 to 6, wherein two of said elastic supporting members arranged in parallel approximately in the focus direction have a slope portion.

[Claim 8] The objective lens driving device for the optical disk according to any of claims 4 to 7, wherein two of said elastic supporting members arranged in parallel approximately in the focus direction have a bent portion bent approximately in a tracking direction.

[Claim 9] The objective lens driving device for the optical disk according to any of claims 4 to 6, wherein two of said elastic supporting members arranged in parallel approximately in the focus direction have a bent portion approximately in a shape of a square with one side opened.

[Claim 10] The objective lens driving device for the optical disk according to any of claims 4, 5 and 9, wherein said elastic supporting members arranged in parallel approximately in the focus direction have said respective bent portions at the same position from the fixed portion, and bending lengths of said bent portions are different.

[Claim 11] The objective lens driving device for the optical disk according to any of claims 4, 5 and 9, wherein said elastic supporting members arranged in parallel approximately in the focus direction have said bent portions at different positions from the fixed portion, and bending lengths of said bent portions are the same.

[Claim 12] The objective lens driving device for the optical disk according to any of claims 4 to 11, wherein said elastic supporting member is provided in such a way that a straight line connecting fixing positions on the sides of said movable portion and said fixed portion is approximately in parallel with a disk surface.

[Claim 13] The objective lens driving device for the optical disk according to any of claims 4 to 12, wherein an arm portion and a protruding portion of free ends branched from said elastic supporting member are connected by a damper material near said at least one bent portion of said elastic supporting member.

[Claim 14] An optical recording/reproducing apparatus using, for recording, reproducing and erasing optical information, the objective lens driving device for the optical disk recited in any of claims 4 to 13.

[Claim 15] The optical recording/reproducing apparatus according to claim 14, wherein said optical recording/reproducing apparatus records, reproduces and erases optical information with use of a light source having a short wavelength of violet or blue.

[Detailed Description of the Invention]

[Technical Field to Which the Invention Belongs]

The present invention relates to tilt correction methods of a movable portion, tilt correction methods of an objective lens for an optical disk, and objective lens driving devices for an optical disk. More specifically, the present invention relates to a tilt correction method of a movable portion, tilt correction method of an objective lens for

an optical disk, and an objective lens driving device for an optical disk for recording/reproducing information with respect to an optical disk of an optical information recording medium such as an MD, CD-ROM, and DVD.

[Prior Art]

An optical recording/reproducing apparatus collects/scans as small spots of light beams over an information recording track of an optical disk for recording and erasing information. The optical recording/reproducing apparatus reads reflection of the light beam directed to an information recording surface for reproducing information.

When such an optical recording/reproducing apparatus records information, for example, the optical disk which is rotating at high speed may be subjected to surface vibration, decentering, and rotation oscillation. Accordingly, to reliably record, erase and reproduce information with respect to the optical disk, spots of light beams have to precisely follow the track even in the event of surface vibration or the like.

To meet this need, an objective lens for an optical disk used in an optical recording/reproducing apparatus is conventionally provided with a drive control mechanism which includes a focus servo mechanism adapted to slightly move in the perpendicular direction (optical axis direction) with respect to a disk surface, and a tracking servo mechanism adapted to slightly move in the radial direction with respect to the disk surface (orthogonal direction with respect to a recording track). The drive control mechanism has constantly provided positional control of an objective lens for an optical disk.

Now, a brief description of an objective lens driving device for an optical disk provided with a conventional drive control mechanism will be given with reference to the drawings. Fig. 37 is a side view of an objective lens driving device for an optical disk 101 used for explaining a positional relationship between objective lens driving device for optical disk 101 and an optical disk 10 in the conventional art. Fig. 38 shows an objective lens driving device for optical disk 101 when viewed from above.

As shown in Figs. 37 and 38, objective lens driving device for optical disk 101 is

positioned below optical disk 10. The direction perpendicular to the surface of optical disk 10 (optical axis direction) is hereinafter defined as the focus direction Fo (the direction indicated by an arrow Fo in the drawing), the direction parallel to the surface of optical disk 10 and perpendicular to the track direction (radial direction of optical disk 10) as the tracking direction Tr (the direction indicated by an arrow Tr in the drawing), and the tangential direction of the disk as the tangential direction Ta (the direction indicated by an arrow Ta in the drawing).

A reflection mirror 9 is provided on a base for guiding a laser beam to objective lens 1. A movable portion includes: an objective lens 1 of a pickup optical system for an optical disk; an objective lens holder 2 for holding objective lens 1 approximately at the center; a pair of hollow focus coils 6 provided on the side walls of objective lens holder 2; and a tracking coil 7 fixed at each focus coil 6. The movable portion is supported by an elastic supporting member 3 of, for example, four parallel metal wires. Elastic supporting member 3 supports the movable portion in such a way to allow its slight movement in focus direction Fo and tracking direction Tr that are orthogonal to the longitudinal direction of elastic supporting member 3.

Elastic supporting member 3 has one end mounted to a mounting member 8 fixed to the side surface of objective lens holder 2 that is orthogonal to tracking direction Tr, and the other end mounted to a fixed portion 11 (an optical base). Elastic supporting member 3 has, on its one or both surfaces (on both surfaces in Fig. 38), a damper material 12 applied thereto. Note that mounting member 8 is used for mounting elastic supporting member 3 and serves to provide electrical communication among focus coil 6, tracking coil 7 (these coils may be hereinafter collectively referred to as "a driving coil"), and metal elastic supporting member 3.

Objective lens driving device for optical disk 101 is further provided with a magnetic circuit which includes a magnet 4 and a yoke 5 for driving objective lens holder 2 in focus direction Fo and tracking direction Tr. Yoke 5 consists of two inner yokes 5(a) and two outer yokes 5(b) which are orthogonal to the optical axis direction.

Two magnets 4 are respectively mounted on the surfaces of two outer yokes 5(b) that face inner yokes 5(a).

Since inner yokes 5(a) are inserted in focus coils 6, objective lens holder 2 fixed to the driving coil can be driven by controlling a current flowing through the driving coil.

Namely, the magnetic circuit formed of magnet 4 and yoke 5 as well as focus coils 6 in the magnetic circuit comprise a dynamoelectric converter which causes movement in focus direction Fo. Thus, by controlling the current in focus coil 6, the driving force in focus direction Fo can be varied. As a result, lens holder 2 mounted with objective lens 1 can be translated in focus direction Fo against the elastic force of elastic supporting member 3.

Further, the magnetic circuit formed of magnet 4 and yoke 5 as well as tracking coil 7 positioned in the magnetic circuit comprise a dynamoelectric converter which causes movement in tracking direction Tr. Thus, by controlling the current in tracking coil 7, the driving force in tracking direction Tr can be varied. As a result, lens holder 2 mounted with objective lens 1 can be translated in tracking direction Tr against the elastic force of elastic supporting member 3.

Here, as a prior art elastic supporting member, an objective lens driving device disclosed in Japanese Patent Laying-Open No. 6-139599 (Japanese Patent No. 2981351) is illustrated. Fig. 39 is a diagram of an elastic supporting member (elastic material) of the objective lens driving device when viewed from above. Linear portions 3a and 3b, respectively extending from the movable and fixed portion sides of elastic supporting member 3, are not collinear. Elastic supporting member 3 has a bent portion 3c between linear portions 3a and 3b (elastic supporting member 3 has a portion bent in tracking direction Tr).

A damper material 12 is fixed to connect an arm portion 3d branching from linear portion 3a extending from the movable portion side and a protruding portion 3e. Elastic supporting member 3 is in the form of a leaf spring with a damper material 12 that has a damping effect applied on one or both surfaces.

The bent portion and damper material of the elastic supporting member serve to suppress vibration of the movable portion in focusing direction Fo and tracking direction Tr and suppress expansion/contraction or torsional oscillation in the longitudinal direction. Thus, a resonance peak is restrained to provide stable driving control.

[Problems to be Solved by the Invention]

However, the above described prior art objective lens driving device for the optical disk suffers from the following problems.

The above described prior art objective lens driving device for optical disk tends to deform (expand/contract) in the longitudinal direction because of the bent portion of elastic supporting member 3. For example, as shown in schematic side views of (a), (b) and (c) of Fig. 40, when objective lens 1 is vertically moved in focus direction Fo, it tilts in a specific direction. Namely, the optical axis (solid lines in the drawings) of objective lens 1 are inclined.

(b) of Fig. 40 shows that the movable portion is in a neutral position and the optical axis is not inclined. (a) of Fig. 40 shows that objective lens 1 is moved upwardly in focus direction Fo. (c) of Fig. 40 shows that objective lens 1 is moved downwardly in focus direction Fo. As shown in (a) of Fig. 40, when objective lens 1 is moved upwardly in focus direction Fo, the optical axis is inclined toward fixed portion 11 (+ side) in the Ta direction (tangential direction) in the drawing. As shown in (c) of Fig. 40, when objective lens 1 is moved downwardly in focus direction Fo, the optical axis is inclined toward the side opposite fixed portion 11 (– side) in the Ta direction (tangential direction) in the drawing.

If objective lens 1 is inclined as described above, deflection of elastic supporting member 3 produces a moment on the movable portion. For example, if the supporting interval of four parallel elastic supporting members 3 (having a length of 11.45 mm) is 8.26 mm in width and 2.91 mm in height and objective lens 1 is vertically moved by 0.4 mm in focus direction Fo, when elastic supporting member 3 has a bent portion, a tilt amount would be about ±7.6' in the Ta direction. On the other hand, if the elastic

supporting member has an linear shape without any bent portion (in this case deformation is unlikely to occur in the longitudinal direction), the tilt is caused by deformation of elastic supporting member 3, and hence the tilt would be no more than about ±0.4' in the Ta direction.

Further, the tilt is affected by the supporting interval of elastic supporting member 3. Fig. 41 is a graph showing a relationship between the interval of the elastic supporting members in the height direction and a tilt amount of the optical axis of the objective lens when only the interval in the height direction is varied in the case of the above described elastic supporting member 3. It also represents the tilt amount of the optical axis when objective lens 1 is moved upwardly in focus direction Fo by 0.4 mm. As can be seem from Fig. 41, the smaller the interval between the elastic supporting members in the height direction is, the greater the tilt amount of the objective lens optical axis is. As the movable portion is reduced in size and thickness, the interval of the elastic supporting members in the height direction decreases and the tilt amount of the objective lens optical axis increases, whereby the problem becomes more serious.

In recent years, the amount of information that an optical recording/reproducing apparatus is required to process is rapidly increased. It is desired that a recording surface density for optical recording is considerably increased accordingly. The recording surface density can be increased for example by reducing the wavelength of a light source or by providing an objective lens with greater numerical aperture. As to the former method of reducing the wavelength of the light source in the optical recording/reproducing apparatus, although light sources having a wavelength of about 780 nm or 650 nm are primarily used, the usage of light sources is gradually shifting to those of violet or blue having a wavelength of about 400 nm.

To mention the effect of coma aberration, since coma aberration is in inverse proportion to the wavelength of a light source, it increases with reduction in the wavelength of the light source. Accordingly, to reduce coma aberration, a tilt amount on the side of the optical recording/reproducing apparatus must be reduced to about 50-

60 % of the current amount. With the increasing need for reducing the tilt amount in the optical recording/reproducing apparatus, the tilt amount allowed to an actuator is desirably 50 % or lower of the current amount. For example, if the tilt amount of optical axis of the objective lens when the objective lens is vertically moved in focus direction Fo is currently allowed to have about ±7.6' in the Ta direction (with light source wavelength of 780 nm), in the case of a optical recording/reproducing apparatus with a light source wavelength of 410 nm, a tilt amount must be restrained to about ±4'.

Therefore, the present invention is made to solve the aforementioned problems. An object of the present invention is to provide a tilt correction method of a movable portion, a tilt correction method of an objective lens for an optical disk, and an objective lens driving device for an optical disk for correcting a tilt caused when a movable portion is moved, providing accurate recording and reproducing properties even if the movable portion is reduced in size, restraining a resonance peak by suppressing torsional oscillation of an elastic supporting member for signals in focusing and tracking directions, and providing stable driving control of the objective lens driving device.

[Means for Solving the Problems]

In the tilt correction method of the movable portion according to the present invention, the movable portion and a fixed portion are connected by a plurality of elastic supporting members, the movable portion is displaceably provided in the direction orthogonal to the longitudinal direction of the elastic supporting member (hereinafter referred to as the orthogonal direction), and a tilt of the movable portion caused when the movable portion is moved in the orthogonal direction is corrected. By varying expansion/contraction amounts of the plurality of elastic supporting members when the movable portion is moved in the orthogonal direction, the tilt of the movable portion is corrected.

In the above mentioned invention, preferably, each of the plurality of elastic supporting members has at least one bent portion. By varying expansion/contraction amounts of the bent portions of respective elastic supporting members when the

movable portion is moved, the tilt of the movable portion is corrected.

According to the tilt correction method of the movable portion of the present invention, unlike the conventional case where a tilt of a movable portion is caused by a moment produced on the movable portion due to deflection of the elastic supporting member when the movable portion is moved in the orthogonal direction, the provision of the bent portion in the orthogonal direction of the movable portion provides expansion/contraction of the elastic supporting member in the direction against the moment, i.e., the direction offsetting the moment, whereby the tilt of the movable portion can be minimized.

According to the tilt correction method of an objective lens for an optical disk of the present invention, a movable portion holding an objective lens, a fixed portion, and a plurality of elastic supporting members connecting the movable portion and fixed portion and elastically supporting the movable portion in a manner displaceable at least in the focus direction are provided. A tilt of the movable portion caused with movement in the focus direction is corrected. The elastic supporting member has at least one bent portion which is bent approximately in the focus direction. The bent portions of the elastic supporting members positioned in parallel in the focus direction are adjusted to provide expansion/contraction of the elastic supporting members in the direction offsetting a moment caused by the deflection of the elastic supporting member.

According to the tilt correction method of the objective lens for the optical disk, a tilt caused in the focus direction of the objective lens due to the moment produced on the movable portion caused by the deflection of the elastic supporting member as a result of movement in the focus direction of the optical axis of the objective lens can be minimized by expansion/contraction of the elastic supporting members caused in the direction against the moment, i.e., the offsetting direction, by the bent portions extending approximately in the focus direction and toward neighboring elastic supporting members.

The objective lens driving device for an optical disk of the present invention is

provided with a movable portion holding an objective lens, a fixed portion, and a plurality of elastic supporting members connecting the movable portion and fixed portion and elastically supporting the movable portion in a manner displaceable at least in the focus direction. The device is provided with a correction controlling unit for correcting a tilt of the movable portion caused when the movable portion is moved in the focus direction by adjusting deflections of elastic supporting members arranged in parallel in the focus direction to cause expansion/contraction of the elastic supporting members in the direction offsetting moments caused by the deflections of the elastic supporting members.

With this objective lens driving device for optical disk, although a tilt of the objective lens is caused in the focus direction due to a moment of the movable portion produced by the deflection of the elastic supporting member during movement in the focus direction, by adjusting deflections of neighboring elastic supporting members provided approximately in the focus direction to cause expansion/contraction of the elastic supporting members in the direction against the moment, i.e., in the offsetting direction, the tilt of the objective lens can be minimized in the focus direction.

As the movable portion is reduced in thickness, i.e., the interval between the elastic supporting members arranged in parallel in the focus direction decreases, the tilt of the objective lens in the focus direction increases. However, the tilt of the objective lens can be corrected as described above and the interval between the elastic supporting members can be reduced. As a result, the device can be reduced in thickness and size.

In the above described invention, preferably, the elastic supporting member has at least one bent portion approximately in the focus direction for adjustment of deflection.

With this structure, although a tilt is caused to the movable portion due to a moment produced on the movable portion caused by deflection of the elastic supporting member when the movable portion is moved approximately in the focus direction, the bent portion which is bent approximately in the focus direction of the movable portion

causes expansion/contraction of the elastic supporting member in the direction against the moment, i.e., offsetting direction, whereby the tilt of the movable portion can be minimized.

In the above described invention, two elastic supporting members arranged in parallel approximately in the focus direction are symmetric about the center of support in the focus direction.

In the above described invention, preferably, two elastic supporting members arranged in parallel approximately in the focus direction have an inclined portion.

With this structure, expansion/contraction of the elastic supporting member at the bent portion and expansion/contraction of the elastic supporting member at the inclined portion are caused in the opposite directions, considerable expansion/contraction of the elastic supporting member at the bent portion can be offset by the inclined portion. Thus, the bent portion is allowed to have a sufficient bending length, thereby providing a structure facilitating damping which suppresses vibration of the elastic supporting member. As a result, a resonance peak can be restrained.

In the above described invention, preferably, two elastic supporting members arranged in parallel approximately in the focus direction have a bent portion which is bent approximately in the tracking direction.

With this structure, a sufficient damping effect is obtained at the bent portion which is bent in the tracking direction. Further, the tilt of the optical axis of the objective lens can be corrected at the bent portion which is bent in the focus direction, whereby an effect similar to the above mentioned effect can be obtained.

In the above described invention, preferably, two elastic supporting members arranged in parallel approximately in the focus direction both have bent portions generally in a shape of a square with one side opened.

With this structure, although expansions/contractions are caused in opposite directions, since two elastic supporting members both have a bent portion generally in a shape of a square with one side opened, a greater amount of expansion/contraction is

caused at the bent portion in the position where a deflection angle of the elastic supporting member is greater. Thus, the tilt of the objective lens in the focus direction can be corrected and a bending length can be set to produce a sufficient damping effect. Further, the device can be reduced in thickness by reduction of intervals between the elastic supporting members as described above.

In the above described invention, preferably, the elastic supporting members arranged in parallel approximately in the focus direction are provided with the above mentioned bent portions at the same position from the fixed portion, where the bent portion has a different bending length.

In the above described invention, preferably, the elastic supporting members arranged in parallel approximately in the focus direction are provided with the above-mentioned bent portions at different positions from the fixed portion, where the bent portion has the same bending length.

With this structure, the elastic supporting members arranged in parallel approximately in the focus direction have bent portions bending in the same direction with differing bending lengths. The greater bending length provides greater amount of expansion/contraction. Thus, when the objective lens is moved in the focus direction, the elastic supporting member on the side opposite the disk contracts by a greater amount when the objective lens is moved toward the disk in the focus direction, and the elastic supporting member positioned on the disk side contracts by a greater amount when the objective lens is moved toward the side opposite the disk in the focus direction.

As a result, expansion/contraction of the elastic supporting member is caused in the direction against the moment caused by deflection of the elastic supporting member, i.e., the offsetting direction, so that the tilt of the objective lens optical axis can be minimized as described above, and the movable portion can be reduced in thickness in size, providing a structure facilitating damping which suppresses vibration of the elastic supporting member. Thus, a resonance peak can be restrained.

By varying bending positions of the bent portions which are bent in the same

direction of the elastic supporting members arranged in parallel in the optical axis direction, the bent portion at a position with a greater deflection angle is subjected to a greater amount of expansion/contraction. Thus, when the objective lens is moved in the focus direction, the elastic supporting member positioned on the side opposite the disk contracts by a greater amount when the objective lens is moved toward the disk in the focus direction, and the elastic supporting member positioned on the disk side contracts by a greater amount when the objective lens is moved toward the side opposite the disk in the focus direction.

As a result, expansion/contraction of the elastic supporting member is caused in the direction opposite the moment, i.e., the offsetting direction, whereby the tilt of the optical axis of the objective lens can be minimized as described above, and the movable portion can be reduced in thickness and size, providing a structure facilitating damping which suppresses vibration of the elastic supporting member. Thus, a resonance peak can be restrained.

In the above described invention, preferably, the elastic supporting member is provided in such a way that a straight line connecting the fixing positions on the movable portion and fixed portion sides is approximately in parallel with the disk surface.

With the above described structure, the elastic supporting members positioned in parallel in the optical axis direction are asymmetric about the center of support. Thus, although a certain amount of tilt of the objective lens optical axis may be inevitably caused when the objective lens is moved in the tracking direction, such tilt can be minimized by setting a straight line connecting the fixing positions on the movable portion and fixed portion sides to be approximately in parallel with the disk surface.

In the above described invention, preferably, an arm portion and a protruding portion of free ends of the elastic supporting member are connected through a damper material near the above mentioned at least one bent portion of the elastic supporting member.

With the above described structure, a simple structure formed solely of the

elastic supporting member can suppress vibration in the focusing and tracking directions and torsional oscillation of the elastic supporting member, so that a resonance peak can be restrained.

In the optical recording/reproducing apparatus of the present invention, the objective lens driving device for the optical disk is used as a device for recording, reproducing and erasing optical information.

In the above described invention, preferably, the optical recording/reproducing apparatus records, reproduces, and erases optical information with use of a light source of a short wavelength of violet or blue.

With the above described structure, the tilt in the focusing direction can be minimized during movement of the objective lens, so that light spots are favorably and accurately recorded and reproduced with respect to the disk. Even when the light source of a short wavelength of about 400 nm is used, light spots can be favorably and accurately recorded and reproduced with respect to the disk and vibration of the elastic supporting member can be suppressed. As a result, a more stable servo property is obtained. In addition, the overall size of the apparatus can be reduced.

[Embodiments]

First of all, the concept of the present invention will be described with reference to the drawings and mathematical expressions.

Figs. 1 and 2 show that a movable portion 13 is supported by elastic supporting members 3 and fixed portion 11. In Fig. 1, movable portion 13 is supported by two parallel elastic supporting members 3. Fig. 2 shows that movable portion 13 is displaced by δ in the y direction.

Referring to Figs. 1 and 2, a moment M is produced around each elastic supporting member 3. As a result, movable part 13 is inclined by α. Here, a moment produced on movable portion 13 will be considered. First of all, the x axis is defined in parallel with elastic supporting member 3 in the direction orthogonal to the longitudinal direction of elastic supporting member 3, the y axis is defined perpendicular to the x axis,

portion 13 is inclined as shown by a chain-dotted line in the drawing.

Here, the concept of the present invention is that inclination by angle δ by moment M of movable portion 13 is offset by changing the length of each elastic supporting member 3 in the x direction, i.e., by changing the expansion/contraction amount of each elastic supporting member 3 in the x direction.

By way of example, Fig. 3 shows elastic supporting member 3 provided with a bent portion in the y axis direction. Moment M is offset by varying length of the bent portion of elastic supporting member 3 in the x direction. Namely, with the bending length of p, if a displacement amount of elastic supporting member 3 is δ, the length of the bent portion in the x direction at upper elastic supporting member 3 would be greater than a reference length by $a = p \cdot \sin(i)$. The length of the bent portion at lower elastic supporting member 3 in the x direction is smaller than a reference length by $a = p \cdot \sin(i)$. Here, deflection angles i refer to deflection angles at the position where $x = b$. By thus varying the lengths of elastic supporting members 3 during movement of movable portion 13, moment M applied to movable portion 13 is offset and tilt of movable portion 13 can be corrected. Based on the above described concept of the present invention, the embodiments of an objective lens driving device for an optical disk will be described in detail.

First Embodiment

Referring to Fig. 4, the structure of objective lens driving device for optical disk 100 will be described. Note that Fig. 4 is a side view schematically showing an objective lens driving device for optical disk 100 according to a first embodiment of the present invention. An optical disk 10 is shown for clarifying a positional relationship of the device with respect to the optical disk.

Overall Structure of Objective Lens Driving device for Optical Disk 100

Objective lens driving device for optical disk 100 includes: an objective lens 1 of a pickup optical system for an optical disk; a reflection mirror 3 for directing a laser beam to objective lens 1; an objective lens holder 2 for holding objective lens 1

approximately at the center; a pair of hollow focus coils (not shown, having the same structure as the conventional case) provided on side walls of objective lens holder 2; a tracking coils 7 fixed to respective focus coils; and an elastic supporting member 3 of four parallel metal wires supporting objective lens holder 2. Elastic supporting member 3 supports the movable portion including objective lens holder 2 in a manner slightly displaceable in the focus direction Fo and tracking direction Tr orthogonal to the longitudinal direction of elastic supporting member 3.

Further provided are: a mounting member 8 mounting one end of elastic supporting member 3 to objective lens holder 2 and the other end to fixed portion 11 and supplying a current to a driving coil (formed of the focus coil and tracking coil 7); and a magnetic circuit formed of a magnet 4 and yoke 5 for driving objective lens holder 2 in focus direction Fo and tracking direction Tr. Objective lens driving device for optical disk 100 is provided such that objective lens 1 is positioned below a prescribed track of optical disk 10.

The overall structure and driving concept of objective lens driving device for optical disk 100 are similar to those of the prior art, and therefore detailed description of the overlapping portion will not given here.

Structure of Elastic Supporting Member 3

Now, the structure of elastic supporting member 3, which is a key portion of the present embodiment, will be described in detail. Fig. 5 is a side view of objective lens driving device for optical disk 100 showing elastic supporting member 3. Fig. 5 shows movable portion 13 formed of objective lens 1, objective lens holder 2, driving coil (not shown) and the like, fixed portion 11, and elastic supporting member 3 connecting movable portion 13 and fixed portion 11.

Elastic supporting member 3 has a bent portion 3c that makes a linear portion 3a extending from movable portion 13 and a linear portion 3b extending from fixed portion 11 placed on different straight lines. Bent portion 3c extends approximately in the optical axis 14 direction from fixed portion 11 and extends in the direction toward

neighboring elastic supporting member 3.

Fig. 6 is an elevational perspective view of elastic supporting member 3. One example thereof is shown in Fig. 3. Elastic supporting members 3 fixed to fixed portion 11 are on both sides of movable portion 13 to surround a center of gravity of movable portion 13. Elastic supporting members 3 arranged in parallel in the optical axis 14 direction (focus direction Fo) are symmetric about the center of support. It is also desirable that elastic supporting members 3 arranged in parallel in tracking direction Tr are symmetric about the center of support.

Deflection of Elastic Supporting Member 3

Here, deflection amount of elastic supporting member 3 when objective lens 1 of movable portion 13 is displaced in focus direction Fo will be described. Fig. 7 shows in a side view deflection of elastic supporting member 3 when elastic supporting member 3 is a linear beam supported at both ends. In the drawing, elastic supporting member 3 (having a length of 11.45 mm) in a linear shape without a bent portion has one end fixed to fixed portion 11 and the other end fixed to movable portion 13. (a) of Fig. 7 relates to the case where no deformation occurs, and (b) of Fig. 7 relates to the case where deformation of elastic supporting member 3 occurs when the objective lens (movable portion 13) is moved by 0.4 mm toward the disk side (upward) in focus direction Fo. The deflection angle of elastic supporting member 3 is determined depending on the position of elastic supporting member 3 in the longitudinal direction.

Fig. 8 shows a relationship between the longitudinal position (mm) and deflection angle (rad) of a beam (elastic supporting member). A point of 0 in the longitudinal direction of the beam corresponds to the end of elastic supporting member 3 on the movable portion side. A point 11.45 mm in the beam's longitudinal direction correspond to the end of elastic supporting member 3 on the fixed portion side. As shown in Fig. 8, when elastic supporting member 3 is deflexed, deflection angles at both ends of elastic supporting member 3 become 0 and the intermediate point of elastic supporting member 3 attains to a maximum angle.

Fig. 9 shows in a side view deflection of elastic supporting member 3 when the objective lens (driving member) of elastic supporting member 3 having a bent portion of the present embodiment is moved in focus direction Fo. The length of 11.45 mm of elastic supporting member 3 in Fig. 9 includes lengths of linear portions 3a and 3b excluding bent portion 3c. (a) of Fig. 9 relates to the case where deformation does not occur. (b) of Fig. 9 relates to the case where deformation of elastic supporting member 3 occurs when the objective lens (movable portion 13) is moved by 0.4 mm toward the side of the disk (upward) in focus direction Fo. Linear portions 3a and 3b are subjected to deflection of about the same deflection amount and deflection angle as in the case of Figs. 7 and 8.

Here, if the deflection angle at the position of bent portion 3c in the longitudinal direction of elastic supporting member 3 is θ, bent portion 3c of Fig. 9 is also inclined by θ. Thus, the inclination of θ of bent portion 3c increases the length of elastic supporting member 3 in the longitudinal direction by L, as compared with (a) of Fig. 9.

Fig. 10 shows in a side view deflection of elastic supporting member 3 and movement of the movable portion when linear elastic supporting member 3 free from any bent portion, as shown in Fig. 7, is used. Fig. 10 shows that four parallel linear elastic supporting members 3 have one ends fixed to fixed portion 11 and the other ends fixed to movable portion 13. Elastic supporting member 3 arranged in parallel with the focus direction Fo is fixed with supporting interval L1.

In this state, deformation of elastic supporting member 3 and inclination of optical axis 14 are shown when objective lens 1 (movable portion 13) is moved by a distance L toward the disk (upward) in focus direction Fo. When each elastic supporting member 3 is deflexed as shown by a thick line of Fig. 10, a moment M is applied in the arrow direction (clockwise) to movable portion 13, and optical axis 14 tilts by θ2 toward fixed portion 11 in tangential direction Ta with respect to a straight line perpendicular to the disk. The magnitude of θ2 is affected by L1 and L2, material of elastic supporting member 3 (Young's modulus), amount of expansion/contraction in

the longitudinal direction and so on.

Fig. 11 shows in a side view deflection of elastic supporting member 3 and movement of movable portion 13 when elastic supporting member 3 having a bent portion of the present embodiment as shown in Fig. 9 is used. Fig. 11 shows four parallel elastic supporting members 3 each having linear portions 3a, 3b and bent portion 3c. Here, bent portion 3c is bent approximately in the optical axis direction and toward neighboring elastic supporting members 3 as shown by a thick line. Each elastic supporting member 3 has one end fixed to fixed portion 11 and the other end fixed to movable portion 13. The interval of elastic supporting members 3 arranged in focus direction Fo is fixed to L1. In this state, deformation of elastic supporting member 3 and tilt of optical axis 13 when objective lens 1 (movable portion 13) is moved toward the disk (upward) by distance L2 in focus direction Fo are shown.

Function

If deflection angles of upper and lower elastic supporting members 3 in the drawing at the position of bent portions 3c in the longitudinal direction of elastic supporting member 3 are respectively θ3 and θ4, when each elastic supporting member 3 is deflexed as shown by a thick line of Fig. 11, the bent portions of upper and lower elastic supporting members 3 are respectively inclined by θ3 and θ4 along the deflection angles from the original state.

Thus, as compared with the case where deflection occurs when no bent portion is provided, the length of upper elastic supporting member 3 increases in the longitudinal direction by L3, whereas lower elastic supporting member 3 decreases in length in the longitudinal direction by L4. Thus, elastic supporting member 3 expands/contracts to cause tilt in the direction opposite moment M indicated by an arrow of Fig. 10, i.e., toward the side opposite fixed portion 11 in tangential direction Ta. As a result, elastic supporting member 3 acts to offset tilt θ2 of Fig. 10, whereby the tilt of movable portion 13 in tangential direction Ta can be minimized.

For example, each of four elastic supporting members 3 having bent portions 3c

as shown in Fig. 11 is formed of a material of beryllium copper, having a total length of 11.45 mm and a bent portion of a bending length of 0-0.56 mm at the position 9.76 mm from the end on the side of the movable portion. In addition, supporting intervals on the movable portion side in focus direction Fo and tracking direction Tr are respectively set to 2.51 mm and 8.26 mm. Then, tilt of the optical axis in tangential direction Ta when the objective lens is moved by 0.4 mm toward the side of the disk (upward) in focus direction Fo was calculated by analysis. The resultant relationship between "length of bent portion" and "tilt" is shown in Fig. 12. Note that (–) and (+) of tilt values respectively represent tilts of optical axis toward the side opposite fixed portion 11 and toward the side of fixed portion 11 in tangential direction Ta.

As can be seen from Fig. 12, by varying the lengths of bent portions, the tilt of the optical axis can be controlled. The greater the bent portion length is, the greater the tilt amount toward (–) side is. This is because elastic supporting member 3 expands/contracts to cause tilt in the direction opposite moment M as indicated by an arrow in Fig. 10, i.e., toward the side opposite fixed portion 11 in tangential direction Ta. Referring to Fig. 12, the provision of a small bent portion having a length of about 0.01 mm can serve to restrain tilt to 0'. However, since the relationship above is varied by the material, shape, length, supporting interval, position of the bent portion and the like of elastic supporting member 3, the length of the bent portion must be set depending on such parameters. In addition to the length of the bent portion, the position of the bent portion may be changed to control tilt.

Fig. 13 shows the analysis result of a relationship between "position of bent portion" and "tilt." This analysis model is obtained with the length of the bent portion set to 0.56 mm as in the above described model of Fig. 12. As previously stated with reference to Fig. 8, since the deflection angle varies according to the position of the bent portion, the closer the bent portion is to the central portion of elastic supporting member 3 in the longitudinal direction, the expansion/contraction function of elastic supporting member 3 in the longitudinal direction becomes considerable. Thus,

expansion/contraction of elastic supporting member 3 is caused to the direction opposite moment M indicated by an arrow of Fig. 10, i.e., toward the side opposite fixed portion 11 in tangential direction Ta. As a result, a tilt amount toward the side of (–) becomes large. Referring to Fig. 13, by setting bent portion 1 at the position around 11.4 mm, tilt can be restrained to 0'. However, since the relationship above is varied by the material, shape, length, supporting interval, length of bent portion and the like of elastic supporting member 3, the position of the bent portion can be set to enable control depending on such parameters.

Effect

As described above, conventionally, tilt of optical axis 14 of objective lens 1 varies according to moment M applied to movable portion 13 due to deflection of elastic supporting member 3 during movement of movable portion 13 in focus direction Fo. However, the provision of the bent portion bending approximately in the optical axis direction and toward neighboring elastic supporting member 3 in movable portion 13 causes expansion/contraction of elastic supporting member 3 in the direction opposite moment M, i.e., in the offsetting direction, whereby the tilt of optical axis 14 of objective lens 1 can be minimized.

Further, as the movable portion is reduced in thickness, i.e., as the interval between elastic supporting members 3 arranged in parallel in the optical axis direction, tilt of optical axis 14 of objective lens 1 becomes greater. However, with the effect described above, the tilt of objective lens 1 can be corrected to enable reduction in thickness and size of a device.

First Modification

Structure

Fig. 14 is a side view showing a first modification of elastic supporting member 3 of the above described objective lens driving device for optical disk 100. Fig. 15 shows a side view of another example according to the first modification. As shown in Figs. 14 and 15, the distance between upper and lower elastic supporting members 3

arranged in parallel in the direction of optical axis 14 form a slope portion that increases in the direction of optical axis 14 from fixed portion 11 toward movable portion 13. Linear portions 3b and 3a correspond to the slope portion respectively in Figs. 14 and 15.

Here, the function of elastic supporting member 3 (thick solid line) of Fig. 15 when objective lens 1 is moved toward the disk (upward) in focus direction Fo will be described with reference to the side view of Fig. 16.

(a) of Fig. 16 shows only a portion of elastic supporting member 3 of Fig. 15 including linear portions 3b and bent portion 3c extending from fixed portion 11. (b) of Fig. 16 shows a portion of elastic supporting member 3 of Fig. 15 that includes only linear portion 3a.

Function and Effect

As shown in (a) of Fig. 16, the bent portion is inclined along a linear deflection angle. Thus, upper elastic supporting member 3 in (a) of Fig. 16 extends in the longitudinal direction and lower elastic supporting member 3 in the drawing contracts in the longitudinal direction, whereby a straight line connecting leading edges of the bent portions are inclined in the direction indicated by an arrow of (a) of Fig. 16 (counterclockwise).

As shown in (b) of Fig. 16, if the upper and lower elastic supporting members 3 are provided to have a slope portion that increases in the direction of optical axis 14 from fixed portion 11 toward movable portion 13, upper and lower elastic supporting members 3 in the drawing respectively expands and contracts in the longitudinal direction, whereby a straight line connecting the leading edges of linear portion 3a is inclined in the direction indicated by an arrow in (b) of Fig. 16 (clockwise).

By setting bent portion 3c such that the tilt of the bent portion ((a) of Fig. 16) is greater than that of the slope portion ((b) of Fig. 16), expansion/contraction of elastic supporting member 3 is caused in the direction opposite moment M (Fig. 10), i.e., in the offsetting direction, during movement in focus direction Fo. As a result, the tilt of

optical axis 14 of objective lens 1 can be minimized.

Further, the tilt shown in (b) of Fig. 16 can offset the tilt shown in (a) of Fig. 16, so that bent portion 3c is allowed to have a greater length. Accordingly, the length of bent portion 3c becomes sufficiently large, thereby providing a structure facilitating damping that suppresses vibration of elastic supporting member 3. As a result, a resonance peak can be restrained.

In addition, the above mentioned function and effect can be produced in the case of a structure in which linear portion 3b has a slope portion as shown in Fig. 14. By setting bent portion 3c such that the tilt of the bent portion is greater than that of the slope portion, expansion/contraction of elastic supporting member 3 is caused in the direction opposite moment M, i.e., in the offsetting direction, during movement in focus direction Fo. As a result, the tilt of optical axis 14 of objective lens 1 can be minimized. Further, the tilt of bent portion 3c can be offset by the tilt of the slop portion, so that bent portion 3c is allowed to have a greater length. Accordingly, the length of bent portion 3c becomes sufficiently large, thereby providing a structure facilitating damping that suppresses vibration of elastic supporting member 3. As a result, a resonance peak can be restrained.

In the case where both of linear portions 3a and 3b of elastic supporting member 3 have a slope portion, by providing bent portion 3c such that tilt of bent portion 3c is greater than a total tilt amount of linear portions 3a and 3b having the slope portion, the above described effect can be produced.

Second Modification

Structure

Fig. 17 shows a second modification of elastic supporting member 3 in objective lens driving device for optical disk 100. As shown in Fig. 17, elastic supporting member 3 additionally has a bent portion bending approximately in tracking direction Tr, so as to produce an effect similar to that of the above described objective lens driving device for optical disk 100. (a) of Fig. 17 is a side view and (b) of Fig. 17 is a plan

view when seen from the disk side.

As shown in (a) and (b) of Fig. 17, each elastic supporting member 3 has linear portions 3a, 3b, bent portion 3c bending approximately in the direction of optical axis 14 and toward neighboring elastic supporting members 3, and a bent portion 3f bending approximately in tracking direction Tr. In this configuration, bent portion 3c is provided such that bent portion 3f offsets greater tilt in the direction of moment M (tilt toward fixed portion 11 in tangential direction Ta) by tilt (tilt in the direction opposite fixed portion 11 in tangential direction Ta) of bent portion 3c.

Function and Effect

Thus, expansion/contraction of elastic supporting member 3 is caused in the direction opposite moment M, i.e., in the offsetting direction, during movement of movable portion 13 in focus direction Fo, whereby tilt of optical axis 14 of the objective lens can be minimized. Further, bent portion 3f may have a sufficiently large length, thereby providing a structure facilitating damping that suppresses vibration of elastic supporting member 3. Thus, a resonance peak can be restrained.

The above described elastic supporting member 3 shown in Fig. 17 can be manufactured by forming a structure having linear portions 3a and 3b and bent portion 3f which is bent in tracking direction Tr by means of etching or the like, and then bending linear portion 3a to form bent portion 3c which is bent from fixed portion 11 approximately in the direction of optical axis 14 and toward neighboring elastic supporting member 3.

Alternatively, elastic supporting member 3 may be manufactured by forming a structure having linear portions 3a, 3b and bent portion 3c by etching or the like and then bending linear portion 3b to provide bent portion 3f which is bent in tracking direction Tr.

Third Modification

Structure

Fig. 18 shows a third modification of elastic supporting member 3 in objective

lens driving device for optical disk 100. Another example of the third modification is shown in Fig. 19. As shown in Figs. 18 and 19, elastic supporting member 3 includes linear portions 3a, 3b and bent portion 3c which is bent from fixed portion 11 approximately in the direction of optical axis 14 and toward neighboring elastic supporting member 3. It further has a second bent portion 3g which is bent from fixed portion 11 approximately in the direction of optical axis 14 and toward neighboring elastic supporting member 3 at the position where a deflection angle (a deflection angle when objective lens 1 is moved) of elastic supporting member 3 is smaller than that of a bent portion 3c.

Function and Effect

Elastic supporting member 3 having the above described structure can minimize tilt of optical axis 14 of objective lens 1 as in the case of the previously described each elastic supporting member 3. Here, the graph of Fig. 20 shows a relationship between the position in the longitudinal direction and a deflection angle of the linear beam shown in Fig. 8. (a) and (b) of Fig. 20 respectively relate to upper elastic supporting members 3 of Figs. 18 and 19, showing a relationship between bent portions 3c, 3g of each elastic supporting member 3 and a deflection angle.

(a) and (b) of Fig. 20 respectively relates to bent portions 3c and 3g. It can be seen that the bending position of bent portion 3c is at the position where a deflection angle is greater than that of bent portion 3g. In this configuration, expansions/contractions are caused in the opposite directions since bent portions 3c and 3g are bent in the opposite directions from fixed portion 11. As a result, bent portion 3c that is positioned at the portion where the deflection angle of elastic supporting member 3 is greater produces a greater effect of expansion/contraction. Thus, upper and lower elastic supporting members 3 act in the same manner, so that the tilt of optical axis 14 of objective lens 1 can be corrected. In addition, since tilt of bent portion 3c can be offset by that of bent portion 3g, the bending length that is enough to produce a sufficient damping effect can be ensured. Further, the distance between elastic

supporting members 3 can be further reduced as in the above described case, thereby enabling reduction in thickness of the device.

Fourth Modification

Structure

Fig. 21 shows a fourth modification of elastic supporting member 3 in the objective lens driving device for optical disk. At least one pair of elastic supporting members 3 are arranged in parallel in the direction of optical axis 14 of objective lens 1. Elastic supporting member 3 has a bent portion 3h bending approximately in the direction of optical axis 14 from fixed portion 11 and toward the side opposite neighboring elastic supporting member 3. Elastic supporting members 3 positioned in parallel in the direction of optical axis 14 are symmetric about the center of support. The distance between elastic supporting members 3 decreases from the fixed portion side toward the movable portion side in the direction of optical axis 14, forming linear portion 3a with a slope.

Function and Effect

As in the above described each elastic supporting member 3, elastic supporting member 3 of the fourth modification can minimize tilt of optical axis 14 of objective lens 1.

In this configuration, bent portion 3h is provided such that tilt of linear portion 3a having a slope is greater than that of bent portion 3h. Thus, expansion/contraction of elastic supporting member 3 is caused in the direction opposite moment M, i.e., in the offsetting direction, during movement of movable portion 13 in focus direction Fo, whereby tilt of optical axis 14 of the objective lens can be minimized. Further, since the tilt of bent portion 3h can be offset by that of linear portion 3a having a slope, bent portion 3h is allowed to have a sufficiently large length. As a result, a structure facilitating damping that suppresses vibration of elastic supporting member 3 is provided and a resonance peak can be restrained.

Note that the above described function and effect are not limited to the case

where linear portion 3a of elastic supporting member 3 has a slope. The similar effect can be produced when linear portion 3b has a slope portion or both of linear portions 3a and 3b have slope portions if bent portion 3h and the slope portions are adjusted such that tilt of linear portion 3a with the slope is greater than that of bent portion 3h.

Fifth Modification

Structure

Fig. 22 shows a fifth modification of elastic supporting member 3 in objective lens driving device for optical disk 100. As shown in Fig. 22, at least one pair of elastic supporting member 3 are arranged in parallel in the direction of optical axis 14 of objective lens 1, each elastic supporting member 3 positioned in the direction of optical axis 14 has a bent portion 3i which is bent from fixed portion 11 approximately in the direction of optical axis 14 and in the direction toward the optical disk. Bent portion 3i of elastic supporting member 3 that is closer to the disk (elastic supporting member 3 on the upper side of the drawing) is shorter in length.

Function and Effect

Elastic supporting member 3 having the above described configuration can minimize tilt of optical axis 14 of objective lens 1 as in the case of the above described elastic supporting member 3. Bent portion 3i of lower elastic supporting member 3 that is bent in the same direction from fixed portion 11 is made longer. For example, when objective lens 1 is moved toward the disk (upward) in focus direction Fo, lower elastic supporting member 3 contracts to a large extent in the longitudinal direction. As a result, expansion/contraction of elastic supporting member 3 is caused in the direction opposite moment M due to deflection of elastic supporting member 3, i.e., in the offsetting direction. Thus, tilt of optical axis 14 of objective lens 1 can be minimized.

To give details of Fig. 22, for example, each elastic supporting member 3 is formed of a beryllium copper. Elastic supporting member 3 has a total length of 11.45 mm. Bent portion 3i is positioned 9.76 mm from the end on the side of movable

portion 13, and the longer bent portion has a fixed length of 0.56 mm. The supporting interval on the side of movable portion 13 in focus direction Fo is 2.91 mm and that in tracking direction Tr is 8.26 mm.

Fig. 23 shows a result obtained by analysis with this structure for optical axis tilt in tangential direction Ta when objective lens 1 is moved toward the disk (to the upper side) by 0.4 mm in focus direction Fo. In Fig. 23, the abscissa represents "length of shorter bent portion" and the abscissa represents "tilt" of optical axis 14 in tangential direction Ta (tilt values of (+) and (–) respectively represent tilt toward fixed portion 11 and toward the side opposite the fixed portion). As can be seen from Fig. 23, in the above described configuration, the shorter bending length is set to 0.36 mm, so that tilt in tangential direction Ta can be restrained approximately to 0'.

In addition, the distance between elastic supporting members 3 can be reduced to enable reduction in thickness and size of movable portion 13. A bending length that is required for providing damping that suppresses vibration of elastic supporting member 3 can be ensured for upper and lower elastic supporting member 3, whereby a resonance peak can be restrained.

Structure

Fig. 24 shows another example of the above described fifth modification. As shown in Fig. 24, at least one pair of elastic supporting members 3 are arranged in parallel in the direction of optical axis 14 of objective lens 1. Each elastic supporting member 3 has a bent portion 3j which is bent approximately in the direction of optical axis 14 from fixed portion 11 and in the direction opposite the disk side. Bent portion 3j of elastic member 3 positioned closer to the disk (an elastic supporting member positioned on the upper side of the drawing) has a greater length.

Function and Effect

Similarly to elastic supporting member 3 shown in Fig. 22, elastic supporting member 3 having the above described structure can minimize tilt of optical axis 14 of objective lens 1. Bent portion 3j of upper elastic supporting member 3 that is bent in

the same direction (in the direction opposite the disk) from fixed portion 11 is made longer. For example, when objective lens 1 is moved toward the disk (upward) in focus direction Fo, upper elastic supporting member 3 expands to a large extent in the longitudinal direction. As a result, expansion/contraction of elastic supporting member 3 is caused in the direction opposite moment M due to deflection of elastic supporting member 3, i.e., in the offsetting direction. Thus, tilt of optical axis 14 of objective lens 1 can be minimized.

Further, since a distance between elastic supporting members 3 can be reduced, reduction in thickness and size of the movable portion is enabled. In addition, a bending length required for providing damping that suppresses vibration of elastic supporting member 3 can be ensured for upper and lower elastic supporting members 3, so that a resonance peak can be restrained.

Sixth Modification

Structure

Fig. 25 shows a sixth modification of elastic supporting member 3 in the objective lens driving device for optical disk. At least one pair of elastic supporting members 3 are arranged in parallel in the direction of optical axis 14 of objective lens 1. Elastic supporting member 3 has a bent portion 3i which is bent approximately in the direction of optical axis 14 from fixed portion 11 and in the direction toward the optical disk. Bent portion 3i of elastic supporting member 3 that is closer to the disk is arranged in a position where the deflection angle of elastic supporting member 3 is smaller.

As shown in Fig. 26 of another example of the sixth modification, at least one pair of elastic supporting members 3 are arranged in parallel in the direction of optical axis 14 of objective lens 1. Elastic supporting member 3 has a bent portion 3j that is bent in the direction of optical axis 14 from fixed portion 11 and in the direction opposite the disk. Bent portion 3j of elastic supporting member 3 farther from the disk is arranged in a position where the deflection angle of elastic supporting member 3 is

smaller.

Function and Effect

As in the case of each respective supporting member 3, elastic supporting member 3 showing the above described structure of Figs. 25 and 26 can minimize tilt of optical axis 14 of objective lens 1.

For example, a graph of Fig. 27 shows a relationship between "longitudinal position" and "deflection angle" at the bent portion of the linear beam shown in Fig. 8. (a) and (b) of Fig. 27 respectively relates to upper and lower elastic supporting members 3 shown in Fig. 26. A relationship between the bent portion and deflection angle of each elastic supporting member 3 is shown. As can be seen in Fig. 27, upper bent portion 3j of (a) of Fig. 27 is arranged in a position with a greater deflection angle than lower bent portion 3j of (b) of Fig. 27. With this structure, upper elastic supporting member 3 is displaced to a greater extent in the longitudinal direction of elastic supporting member 3 than lower elastic supporting member 3. Namely, upper elastic supporting member 3 becomes longer in the longitudinal direction, so that expansion/contraction of elastic supporting member 3 is caused in the direction opposite moment M due to deflection of elastic supporting member 3, i.e., in the offsetting direction. As a result, tilt of optical axis 14 of the objective lens can be minimized. In addition, a bending length which is sufficient to produce a damping effect can be ensured, a resonance peak is restrained and the distance between elastic supporting members 3 can be reduced. Thus, the device can be reduced in thickness.

Seventh Modification

Structure

A seventh modification of the objective lens driving device for optical disk is shown. Preferably, as shown in Figs. 28, 29 and 30, a straight line connecting fixing positions on the sides of movable portion 13 and fixed portion 11 is set approximately in parallel with the disk surface.

Function and Effect

With this structure, the optical axis tilt (tilt toward the direction of Tr) when objective lens 1 is moved in tracking direction Tr can be minimized. Because of asymmetry of elastic supporting members 3 arranged in parallel in the direction of optical axis 14 about the center of support, when a straight line connecting fixing positions on the sides of movable portion 13 and fixed portion 11 is not parallel to the disk surface, movement of the objective lens in tracking direction Tr may cause imbalance of elastic supporting members 3 arranged in the tracking direction, whereby tilt may be caused in tracking direction Tr.

More specifically, each elastic supporting member 3 in Fig. 28 is formed of a beryllium copper. Each elastic supporting member 3 has a total length of 11.45 mm. The bent portion is provided in a position 9.76 mm from the end of the movable portion. The longer and shorter bending lengths are respectively 0.56 mm and 0.36 mm. The supporting interval of the movable portions arranged in focus direction Fo is 2.91 mm, and that in tracking direction Tr is 8.26 mm. With this structure, a result of the optical axis tilt in the tangential direction obtained by analysis is 0' when objective lens 1 is moved by 0.4 mm toward the disk side (upper side) in focus direction Fo.

Here, Fig. 31 shows a result of the optical axis tilt in tracking direction Tr obtained by analysis when objective lens 1 is moved by 0.2 mm in the forward direction orthogonal to the sheet of the drawing in tracking direction Tr with the configuration of the above described elastic supporting member 3.

In Fig. 31, the mark ◇ (difference in height of fixed portions) shows that a straight line connecting fixing positions of movable portion 13 and fixed portion 11 is not parallel to the disk surface (there are height differences of 0.36 mm and 0.56 mm respectively on the upper and lower sides) (for example the structure of elastic supporting member 3 shown in Fig. 22). The mark △ (heights of fixed portions are the same) shows that a straight line connecting fixing positions on the sides of movable portion 13 and fixed portion 11 is approximately in parallel with the disk surface.

As can be seen from Fig. 31, by making a straight line connecting fixing

positions on the sides of movable portion 13 and fixed portion 11 approximately in parallel with the disk surface, if the shorter bent portion has a length of 0.36 mm such that the optical axis tilt in tangential direction Ta is 0' when the objective lens is moved by 0.4 mm toward the disk (upper side) in focus direction Fo, the optical axis tilt in tracking direction Tr can be restrained to about 0' when the objective lens is moved by 0.2 mm in the forward direction orthogonal to the sheet of the drawing in tracking direction Tr.

Thus, since neighboring elastic supporting members 3 arranged in parallel in the direction of optical axis 14 are asymmetric about the approximate center of support, the optical axis tilt of objective lens 1 may be caused when objective lens 1 is moved in the tracking direction. However, such tilt of optical axis 14 of the objective lens can be minimized by setting the straight line connecting fixing positions on the sides of movable portion 13 and fixed portion 11 approximately in parallel with the disk surface.

The above discussion relates to elastic supporting member 3 shown in Fig. 28. Even in the case of elastic supporting members 3 respectively shown in Figs. 29 and 30, a similar function and effect can be produced.

Second Embodiment

Structure

Now, referring to Figs. 32 and 33, an elastic supporting member 3 of an objective lens driving device according to the second embodiment of the present invention will be described. As shown in Figs. 32 and 33, elastic supporting member 3 of the present embodiment includes an arm portion 3d of a free end branching from elastic supporting member 3 around at least one bent portion (3c of Fig. 32, 3i of Fig. 33), a protruding portion 3e formed at a connecting portion with respect to fixed portion 11, where at least arm portion 3d and protruding portion 3e are connected by a damper material 12.

Function and Effect

With elastic supporting member 3 of the embodiment, the bent portion (3c of Fig.

32, 3i of Fig. 33) of each elastic supporting member 3, which is bent approximately in the direction of optical axis 14, serves to minimize tilt of optical axis 14 of the objective lens, as stated previously. Further, simple configuration of elastic supporting member 3 suppresses vibrations in focusing direction Fo and tracking direction Tr as well as torsional oscillation of elastic supporting member 3. Thus, a resonance peak can be restrained.

Third Embodiment

Structure

Now, referring to Fig. 34, elastic supporting member 3 of an objective lens driving device of the third embodiment of the present invention will be described. As shown in Fig. 34, a pair of elastic supporting members 3 arranged in the direction of optical axis 14 of objective lens 1 are integrally formed and separated after assembly. Fig. 34 shows that elastic supporting member 3 can be formed by etching a thin plate of a beryllium copper. Two elastic supporting members 3 arranged in parallel in focus direction Fo are connected by a disconnecting portion 3k, which is disconnected after assembly.

Function and Effect

With elastic supporting member 3 of the embodiment, elastic supporting members 3 arranged in parallel in the direction of optical axis 14 are integrally formed to enable facilitate assembly. As compared with the case where two elastic supporting members 3 arranged in parallel in the focus direction are positioned for example with use of a jig for assembly, elastic supporting members 3 are integrally formed, so that a bending position, a tilt angle of the slope portion, vertical arrangement and the like can be more precisely determined. Thus, tilt correction of the optical axis can be more accurately performed.

Fourth Embodiment

Structure

Now, referring to Fig. 35, an optical recording/reproducing apparatus 200 of the

fourth embodiment of the present invention will be described. Fig. 35 is a top view schematically showing optical recording/reproducing apparatus 200 provided with objective lens driving device for optical disk 100 of the first embodiment.

Referring to Fig. 35, optical recording/reproducing apparatus 200 includes a spindle motor 16 for rotating optical disk 10, objective lens driving device for optical disk 17, an optical unit 19 provided with a laser unit or an optical part 18, including various types of lenses and prisms, and a feeding mechanism 20 enabling movement of optical unit 19.

In the above described optical recording/reproducing apparatus 200, feeding mechanism 20 enables movement of optical unit 19 and slight movement of the movable portion of objective lens driving device for optical disk 100 at high speed. Thus, spots of laser beams can follow a prescribed track of optical disk 10 which is rotating at high speed.

Although objective lens driving device for optical disk 100 of the first embodiment is used as an objective lens driving device for optical disk here, any other device may be used.

Fig. 36 shows an analysis result pertaining to transfer properties of a servo system in objective lens driving device for optical disk 100 (using elastic supporting member 3 shown in Fig. 5). An arrow indicated by Fo corresponds to transfer properties of a focus system, and an arrow indicated by Tr corresponds to transfer properties of a tracking system. The ordinate and abscissa respectively represents vibration (dB) and frequency (Hz) in logarithmic representation.

As can be seen from Fig. 36, no resonance is found between frequencies of 100 Hz and 20 kHz after a primary resonant point, exhibiting favorable transfer properties. The above described other shapes of elastic supporting members 3 also exhibited favorable properties.

Function and Effect

As described above, in the optical recording/reproducing apparatus using the

exemplified. However, such a shape, size and material are not limited to those specified above and the structure of the objective lens driving device is not limited to that specified above.

In each of the above described embodiments, a tilt correction method of a movable portion which is a distinguishing feature of the present invention is applied to the tilt correction method for the objective lens of optical disk and the objective lens driving device for optical disk. However, the present invention is not limited to the tilt correction method of the objective lens for optical disk and the objective lens driving device for optical disk. The present invention can also be applied to a device in which a movable portion and fixed portion are connected by a plurality of elastic supporting members and the movable portion is provided in a manner displaceable in the direction orthogonal to the longitudinal direction of the elastic supporting member (hereinafter referred to as the orthogonal direction) and which requires correction of tilt of the movable portion caused when the movable portion is moved in the orthogonal direction.

Although the present invention has been described and illustrated in detail, it is clearly understood that the same is by way of illustration and example only and is not to be taken by way of limitation, the spirit and scope of the present invention being limited only by the terms of the appended claims, and modifications within the scope of the claims and that of the equivalent thereof being intended to be included.

[Effects of the Invention]

According to the tilt correction method for movable portion, tilt correction method for objective lens of optical disk, and objective lens driving device for optical disk of the present invention, by adjusting deflections of neighboring elastic supporting members approximately arranged in the focus direction, expansion/contraction of the elastic supporting members is caused in the direction opposite the moment, i.e., in the offsetting direction, whereby tilt of the objective lens in the focus direction can be minimized. In addition, the tilt of the objective lens can be corrected and the distance between the elastic supporting members can be reduced. As a result, the device can be

reduced in thickness and size.

[Brief Description of the Drawings]

Fig. 1 is a first diagram of a movable portion 13 supported by elastic supporting members 3 and a fixed portion 11 shown in conjunction with an underlying concept of the present invention.

Fig. 2 is a second diagram of a movable portion 13 supported by elastic supporting members 3 and a fixed portion 11 shown in conjunction with an underlying concept of the present invention.

Fig. 3 is a third diagram of a movable portion 13 supported by elastic supporting members 3 and a fixed portion 11 shown in conjunction with an underlying concept of the present invention.

Fig. 4 is a side view schematically showing an objective lens driving device for optical disk 100 according to a first embodiment of the present invention.

Fig. 5 is a side view of elastic supporting member 3 of objective lens driving device for optical disk 100 according to the first embodiment of the present invention.

Fig. 6 is a perspective view of elastic supporting member 3 of objective lens driving device for optical disk 100 according to the first embodiment of the present invention.

Fig. 7 is a side view shown in conjunction with deflection of a linear beam supported at both ends.

Fig. 8 is a graph showing a relationship between a longitudinal position and a deflection angle of the linear beam of Fig. 7.

Fig. 9 is a side view showing a deformation of elastic supporting member 3 of objective lens driving device for optical disk 100 according to the first embodiment of the present invention.

Fig. 10 is a side view of the linear beam used as elastic supporting member 3 during movement of the objective lens.

Fig. 11 is a side view of elastic supporting member 3 of objective lens driving

device for optical disk 100 according to the first embodiment of the present invention during movement of the objective lens.

Fig. 12 is a graph showing a relationship between a length and tilt of a bent portion of elastic supporting member 3 of Fig. 11.

Fig. 13 is a graph showing a relationship between a position and tilt of the bent portion of elastic supporting member 3 shown in Fig. 11.

Fig. 14 is a side view showing a first modification of elastic supporting member 3 of objective lens driving device for optical disk 100 according to the first embodiment of the present invention.

Fig. 15 is a side view showing another exemplary first modification of elastic supporting member 3 of objective lens driving device for optical disk 100 according to the first embodiment of the present invention.

Fig. 16 is a side view shown in conjunction with deformation of elastic supporting member 3 during movement of the optical lens of Fig. 15.

Fig. 17 is a side view showing a second modification of elastic supporting member 3 of objective lens driving device for optical disk 100 according to the first embodiment of the present invention.

Fig. 18 is a side view of a third modification of elastic supporting member 3 of objective lens driving device for optical disk 100 according to the first embodiment of the present invention.

Fig. 19 is a side view of another exemplary third modification of elastic supporting member 3 of objective lens driving device for optical disk 100 according to the first embodiment of the present invention.

Fig. 20 is a graph showing a relationship between a longitudinal position and deflection angle of a bent portion of elastic supporting member 3 shown in Figs. 18 and 19.

Fig. 21 is a side view showing a fourth modification of elastic supporting member 3 of objective lens driving device for optical disk 100 according to the first

embodiment of the present invention.

Fig. 22 is a side view showing a fifth modification of elastic supporting member 3 of objective lens driving device for optical disk 100 according to the first embodiment of the present invention.

Fig. 23 is a graph showing a relationship between a length of a shorter (upper) bent portion and an optical axis tilt of elastic supporting member 3 shown in Fig. 22.

Fig. 24 is a side view showing another exemplary fifth modification of elastic supporting member 3 of objective lens driving device for optical disk 100 according to the first embodiment of the present invention.

Fig. 25 is a side view showing a sixth modification of elastic supporting member 3 of objective lens driving device for optical disk 100 according to the first embodiment of the present invention.

Fig. 26 is a side view showing another exemplary sixth modification of elastic supporting member 3 of objective lens driving device for optical disk 100 according to the first modification of the present invention.

Fig. 27 is a graph showing a relationship between a longitudinal position and deflection angle of a bent portion of elastic supporting member 3 shown in Fig. 26.

Fig. 28 is a side view showing a seventh modification of elastic supporting member 3 of objective lens driving device for optical disk 100 according to the first embodiment of the present invention.

Fig. 29 is a side view showing another exemplary seventh modification of elastic supporting member 3 of objective lens driving device for optical disk 100 according to the first embodiment of the present invention.

Fig. 30 is a side view showing still another exemplary seventh modification of elastic supporting member 3 of objective lens driving device for optical disk 100 according to the first embodiment of the present invention.

Fig. 31 is a graph showing a relationship between a length of the bent portion and optical axis tilt of elastic supporting member 3 shown in Fig. 28 and elastic

supporting member 3 having a fixing portion with different height.

Fig. 32 is a side view showing elastic supporting member 3 according to a second embodiment of the present invention.

Figs. 33 is a side view showing a modification of elastic supporting member 3 according to the second embodiment of the present invention.

Fig. 34 is a top view showing elastic supporting member 3 according to a third embodiment of the present invention.

Fig. 35 is a top view schematically showing an optical recording/reproducing apparatus incorporating objective lens driving device for optical disk 100 according to the first embodiment.

Fig. 36 is a diagram shown in conjunction with a transfer characteristic of a focus system and tracking system of the optical recording/reproducing apparatus.

Fig. 37 is a side view showing objective lens driving device for optical disk 101 of the prior art.

Fig. 38 is a top view showing objective lens driving device for optical disk 101.

Fig. 39 is a top view showing elastic supporting member 3 of objective lens driving device for optical disk 101.

Fig. 40 is a side view of objective lens driving device for optical disk 101 during movement of the objective lens of the prior art.

Fig. 41 is a graph showing a relationship between an interval of elastic supporting members 3 in the height direction and an optical axis tilt of objective lens driving device for optical disk 101 of the prior art.

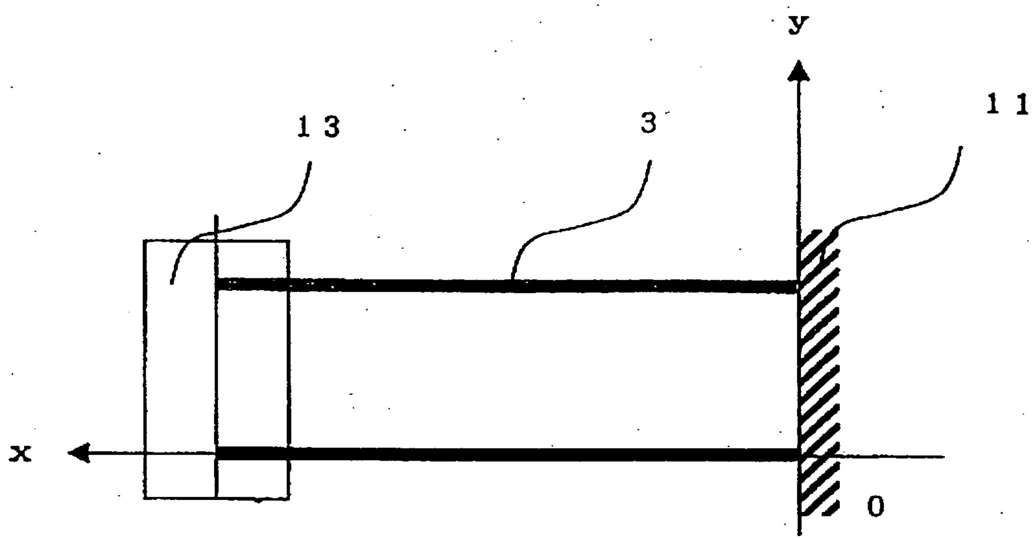
[Description of the Reference Characters]

1 objective lens; 2 objective lens holder; 3 elastic supporting member; 3a, 3b linear portion; 3c, 3f, 3g, 3h, 3i, 3j bent portion; 3d arm portion; 3e protruding portion; 3k disconnecting portion; 4 magnet; 5 yoke; 5a inner yoke; 5b outer yoke; 6 focus coil; 7 tracking coil; 8 mounting member; 9 reflection mirror; 10 optical disk; 11 fixed portion; 12 damper material; 13 movable

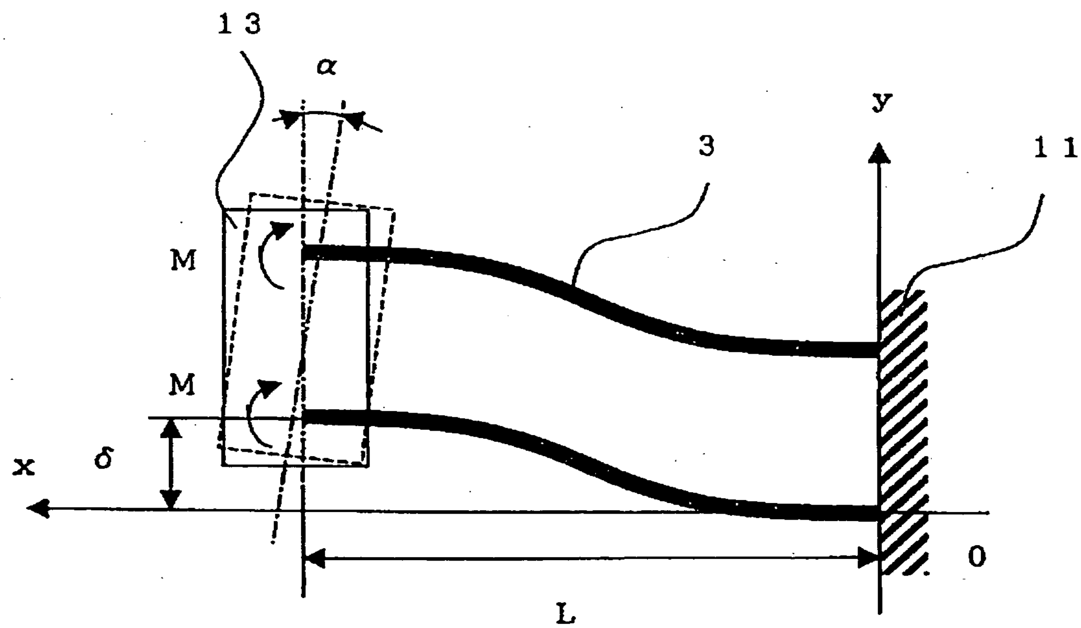
portion; 14 optical axis; 16 spindle motor; 17 objective lens driving device for optical disk; 18 optical part; 19 optical unit; 20 feeding mechanism.

【書類名】　図面　Document Name　Drawings

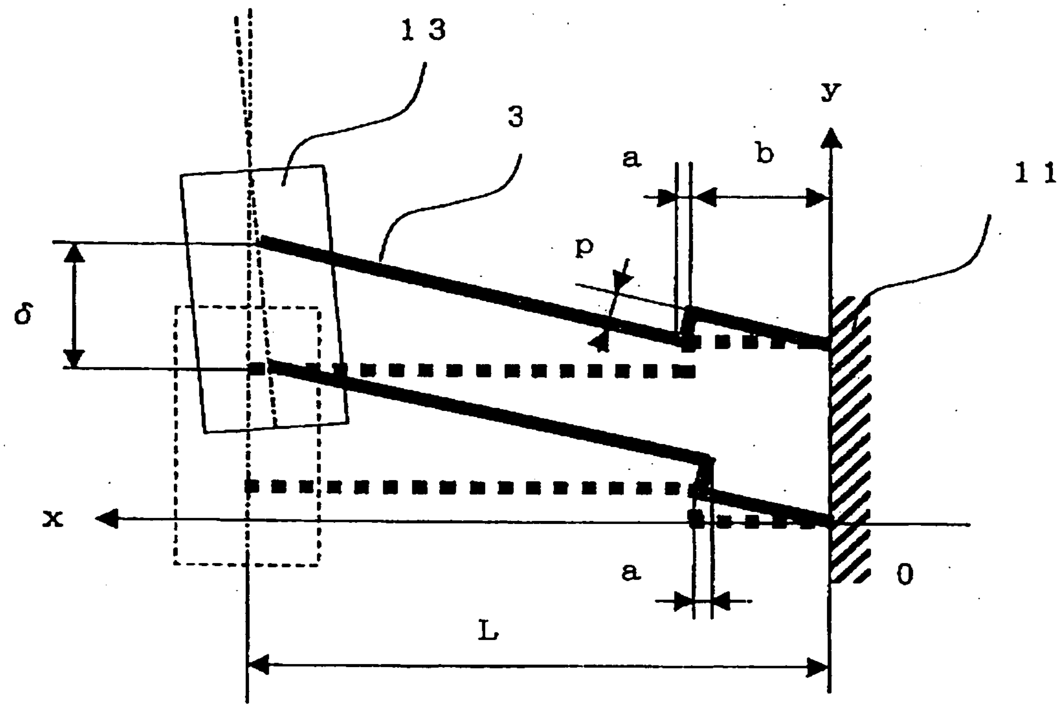
【図１】　Fig. 1



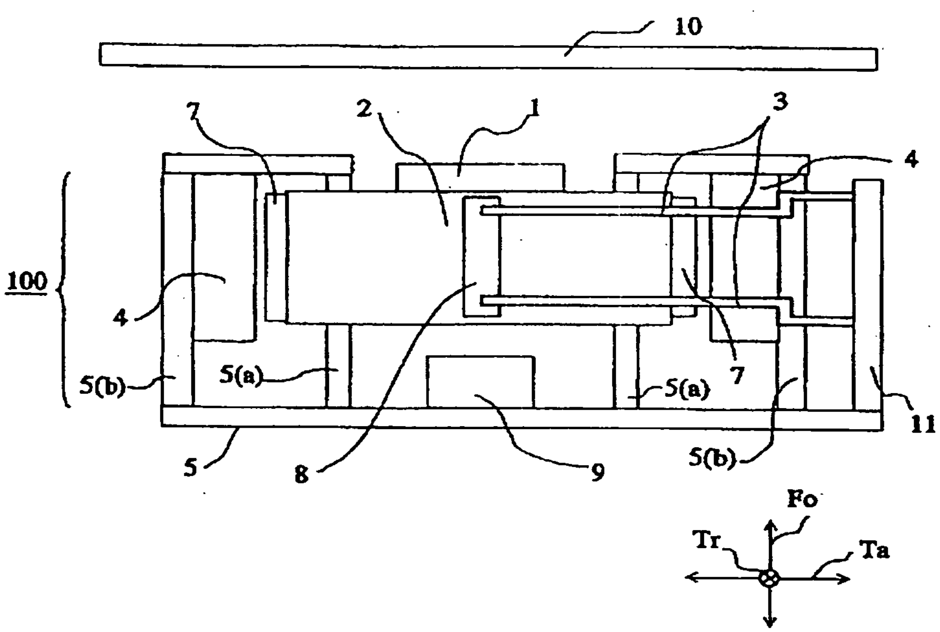
【図２】　Fig. 2



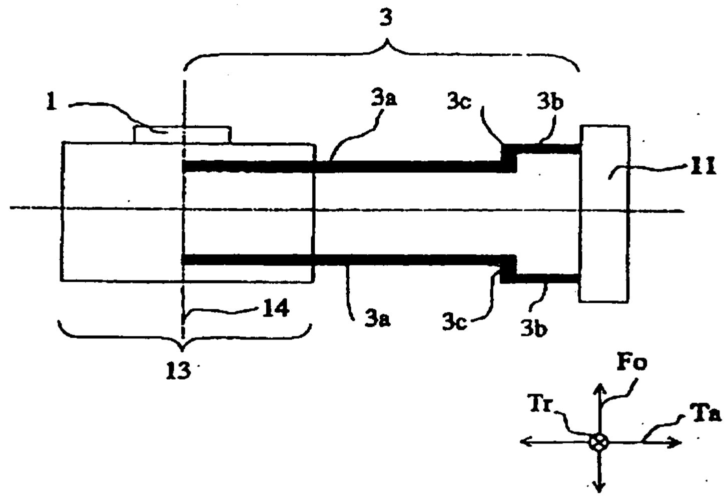
【図３】　Fig. 3



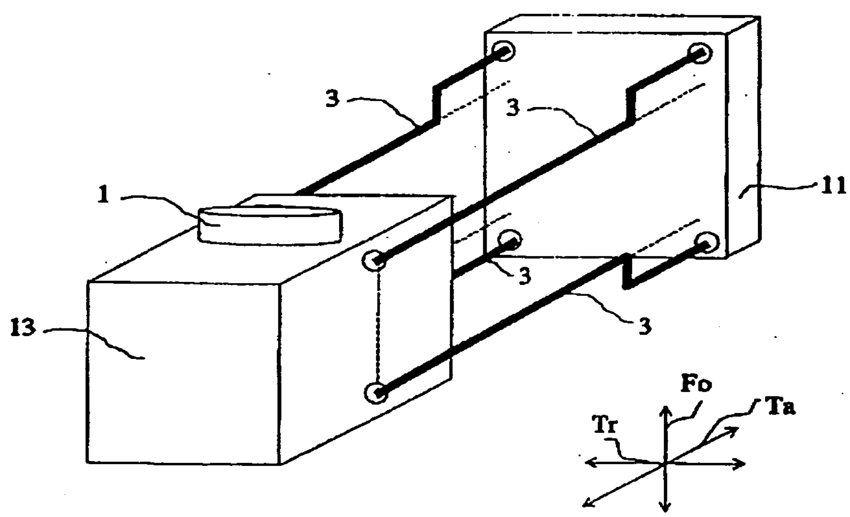
【図４】　Fig. 4



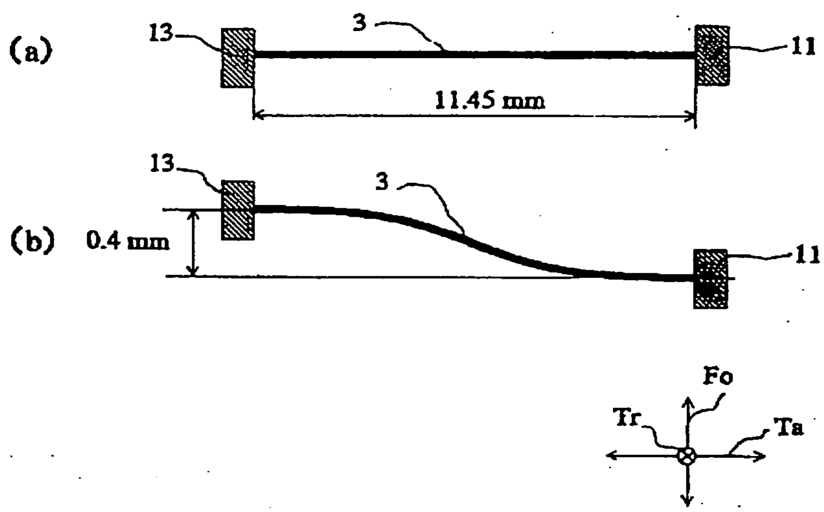
【図５】 Fig. 5



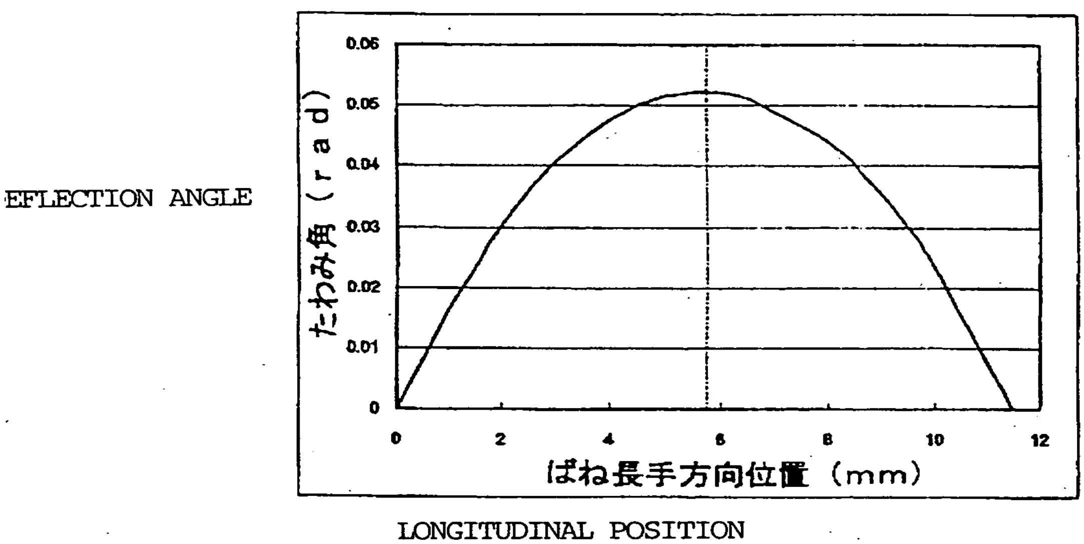
【図６】 Fig. 6



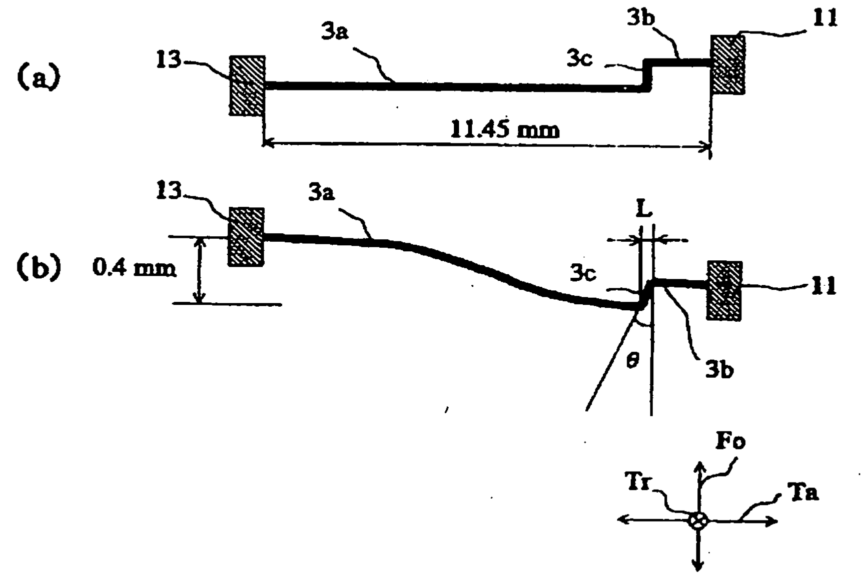
【図７】　Fig. 7



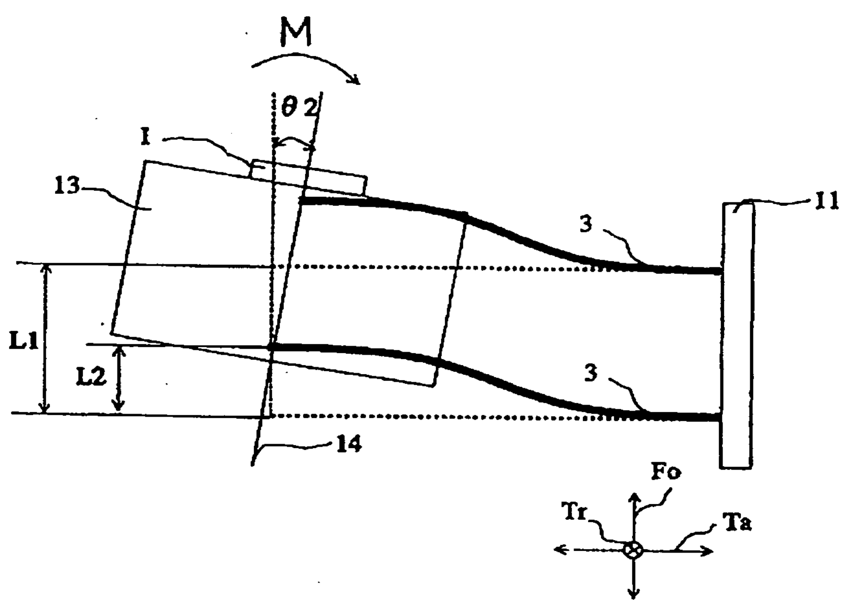
【図８】 Fig. 8



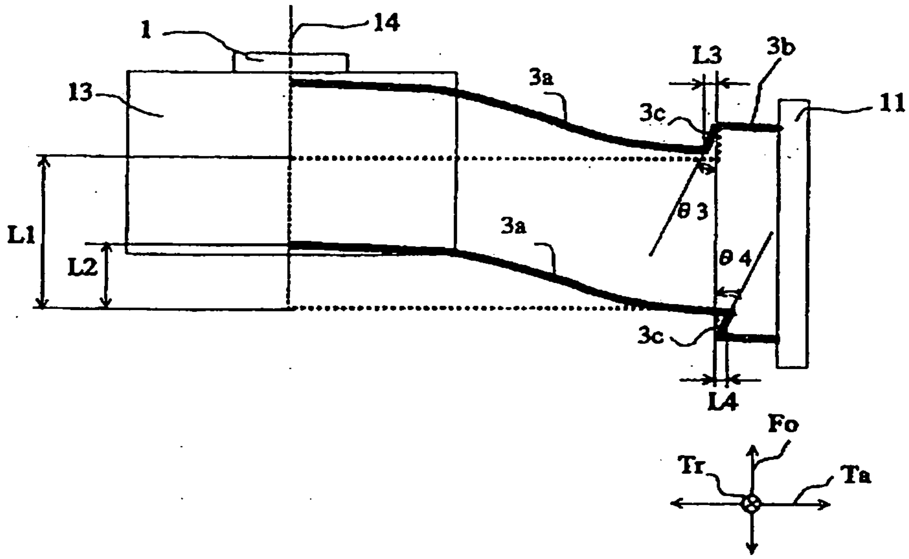
【図９】　Fig. 9



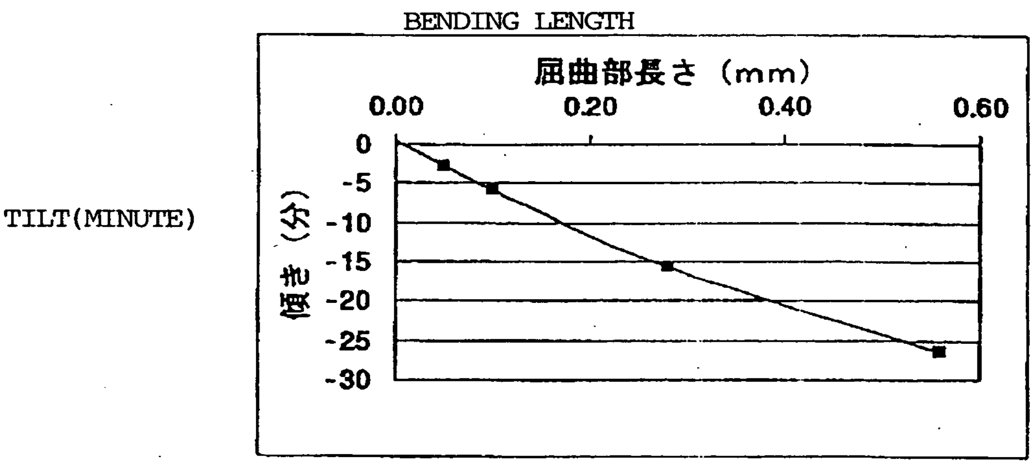
【図１０】 Fig. 10



【図１１】 Fig. 11

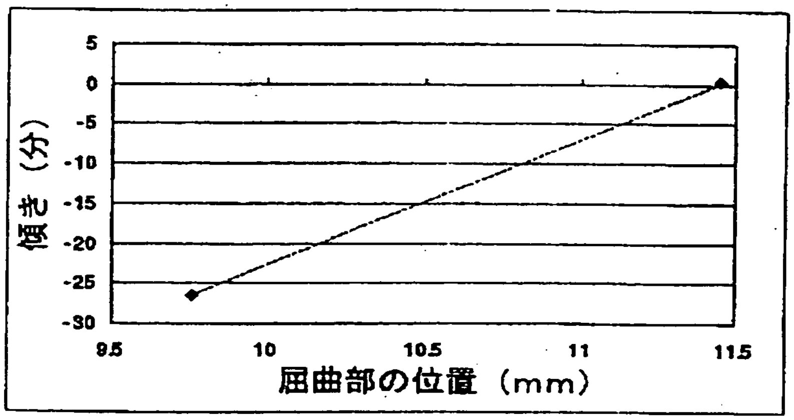


【図１２】 Fig. 12



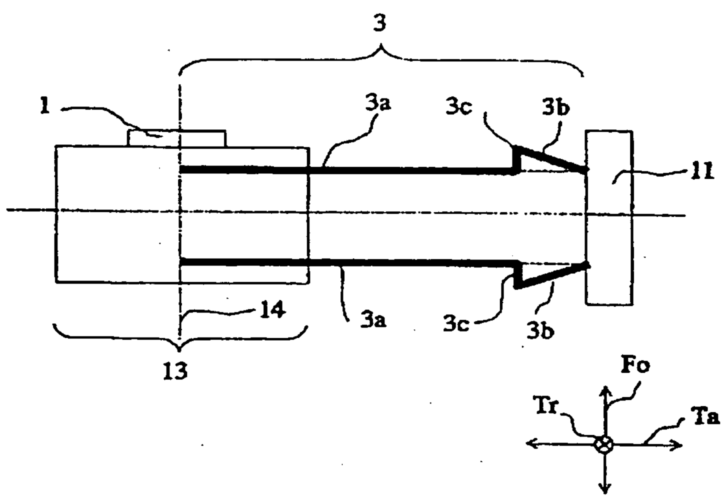
【図１３】　Fig. 13

TILT
(MINUTE)

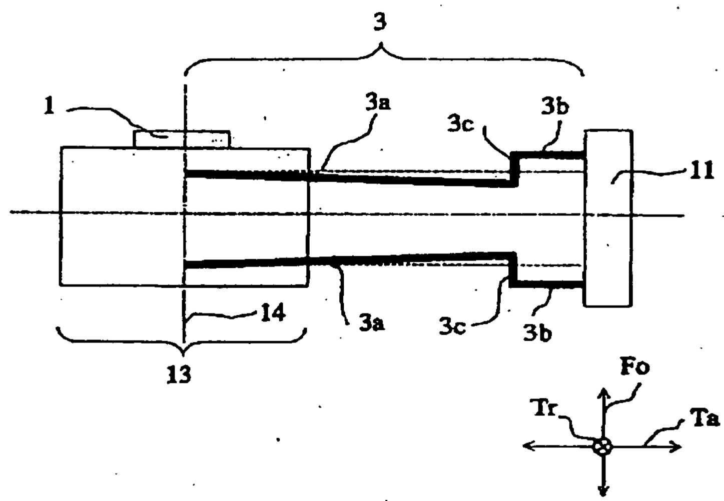


POSITION OF BENT PORTION

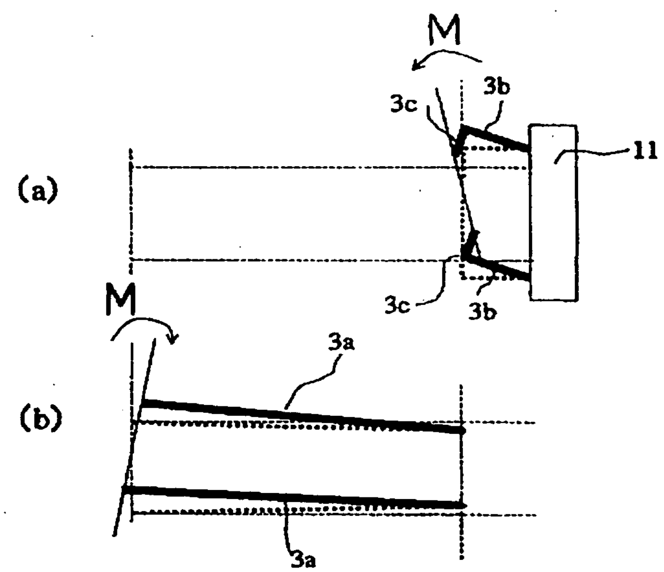
【図１４】 Fig. 14



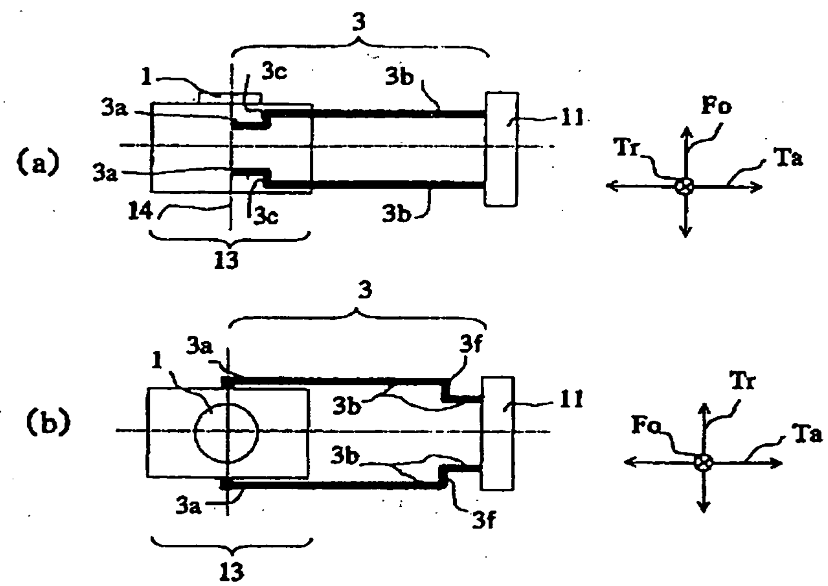
【図１５】 Fig. 15



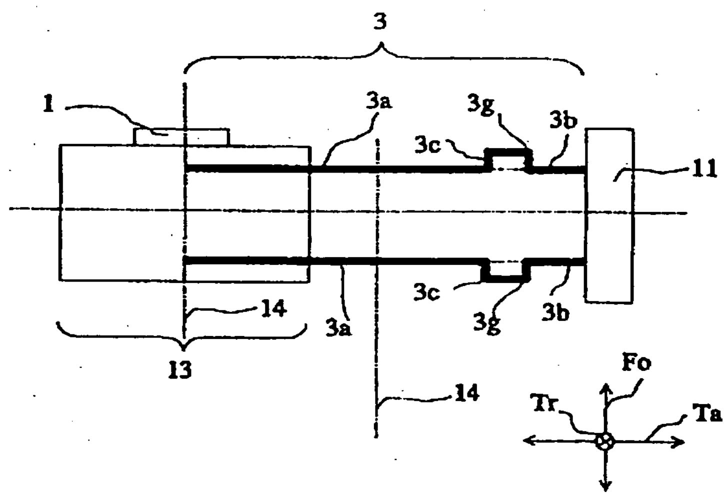
【図１６】Fig. 16



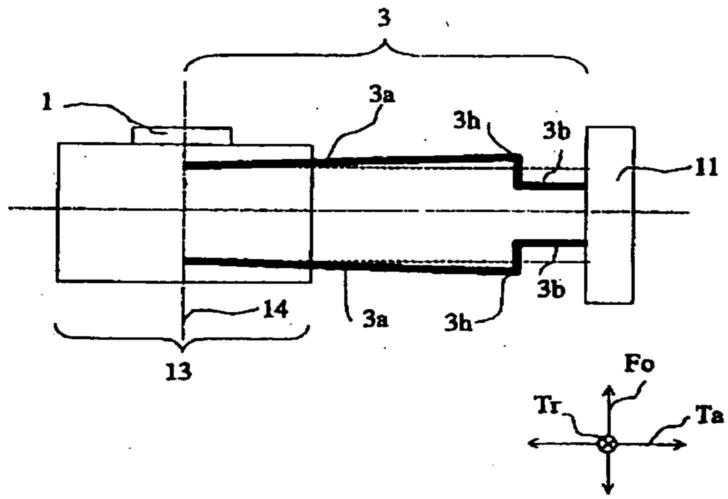
【図１７】 Fig. 17



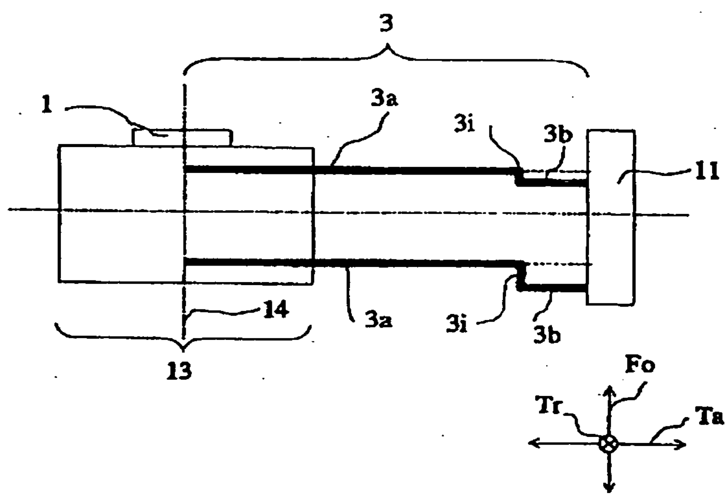
【図１８】 Fig. 18



【図２１】 Fig. 21

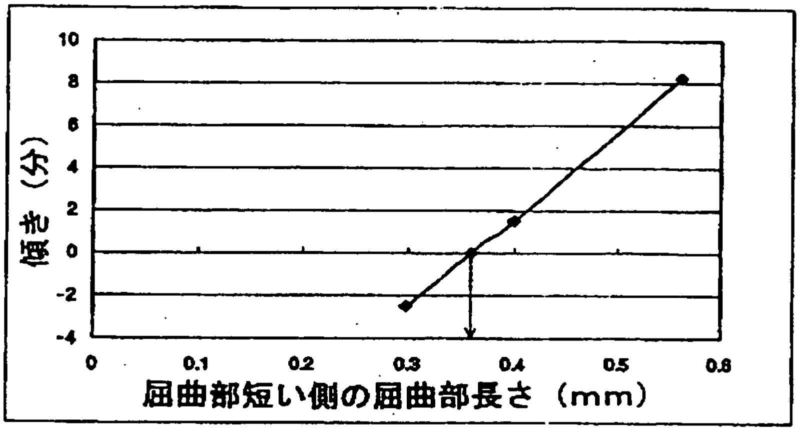


【図２２】 Fig. 22



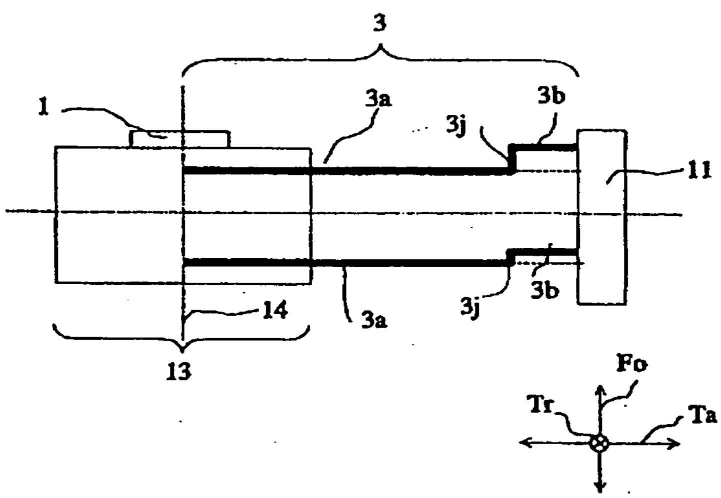
【図２３】 Fig. 23

TILT (MINUTE)

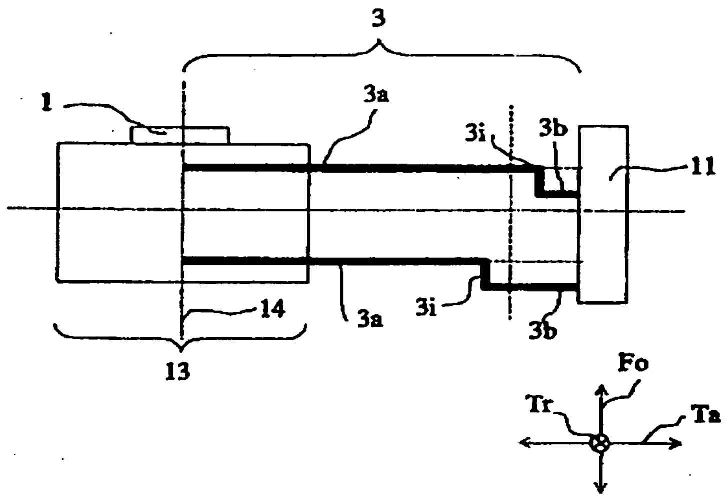


LENGTH OF SHORTER BENDING PORTION

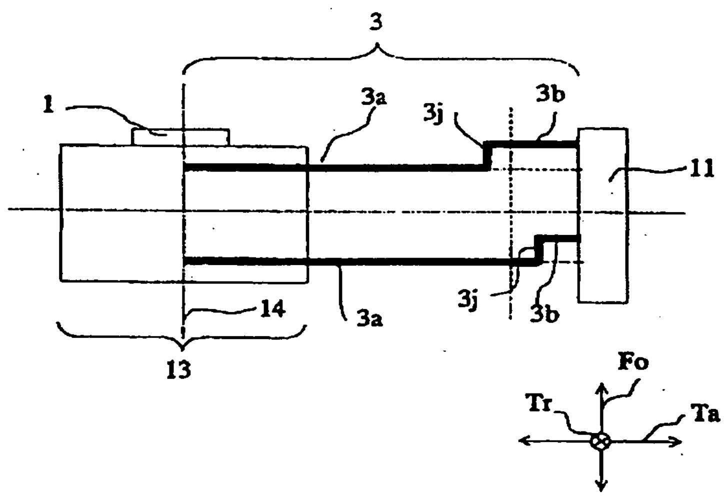
【図２４】 Fig. 24



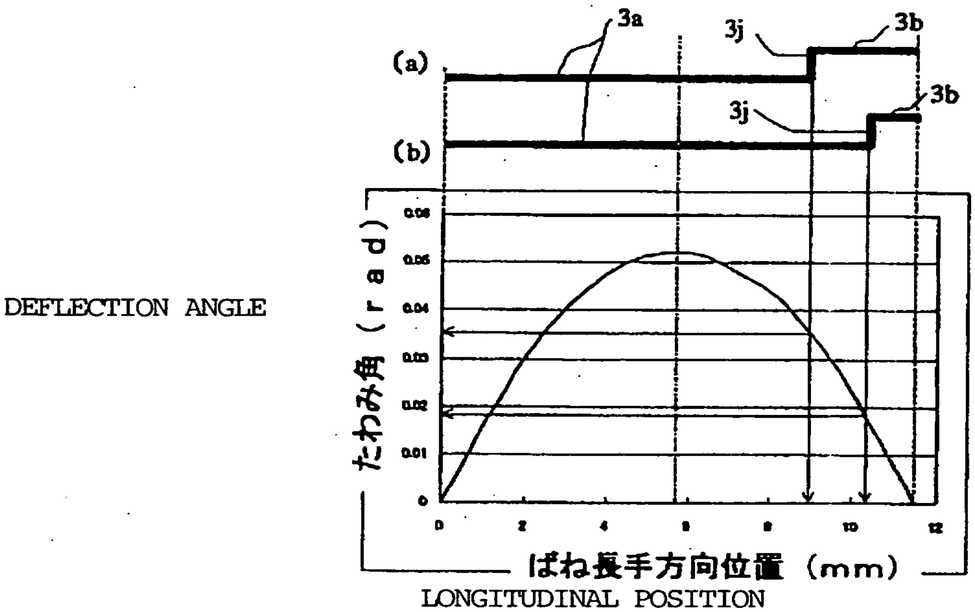
【図２５】　Fig. 25



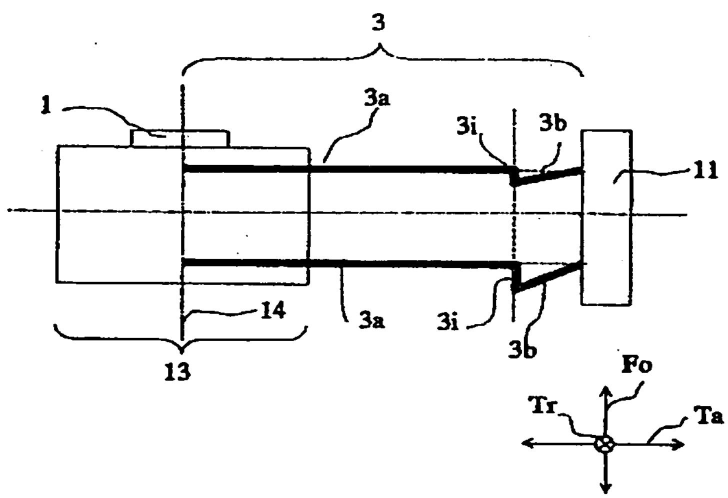
【図２６】　Fig. 26



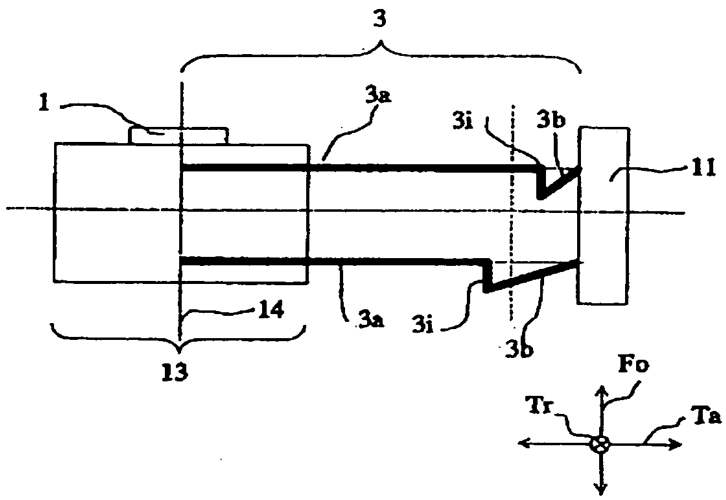
【図２７】　Fig. 27



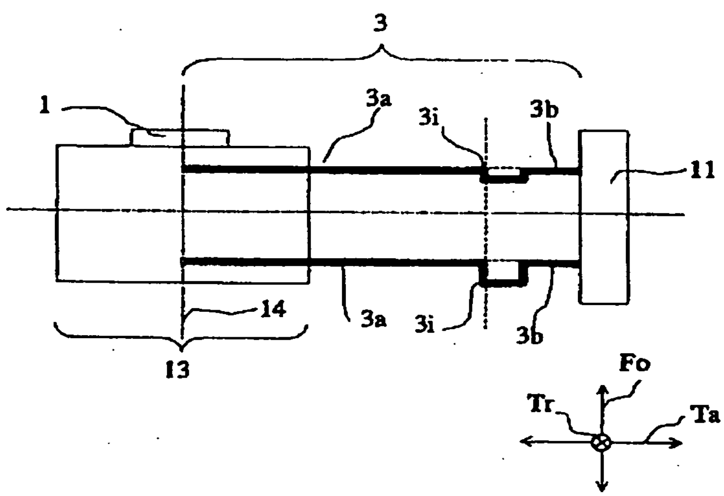
【図２８】　Fig. 28



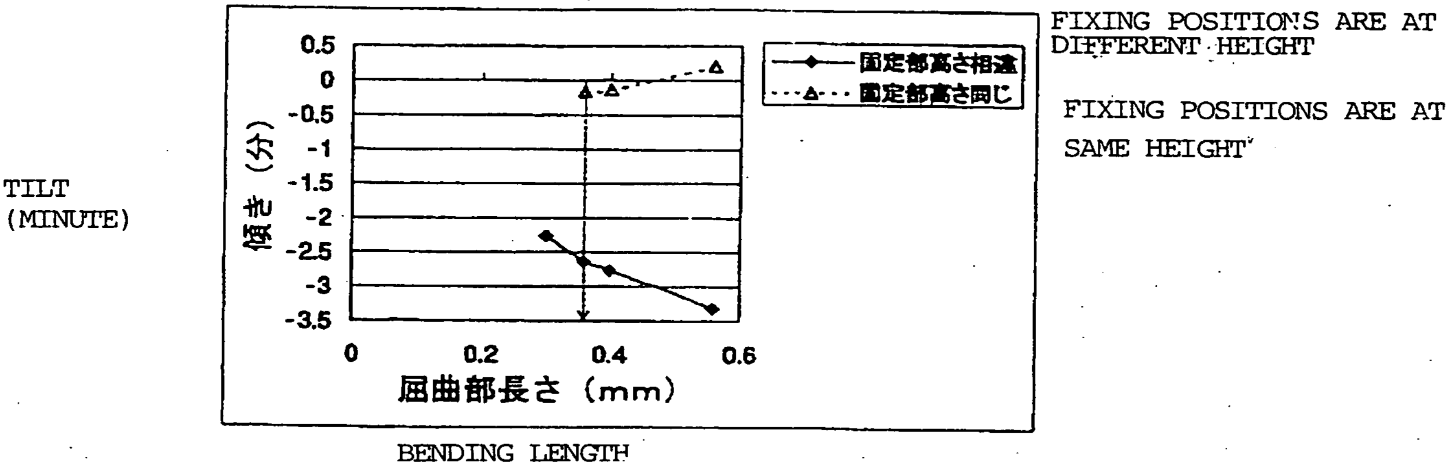
【図２９】　Fig. 29



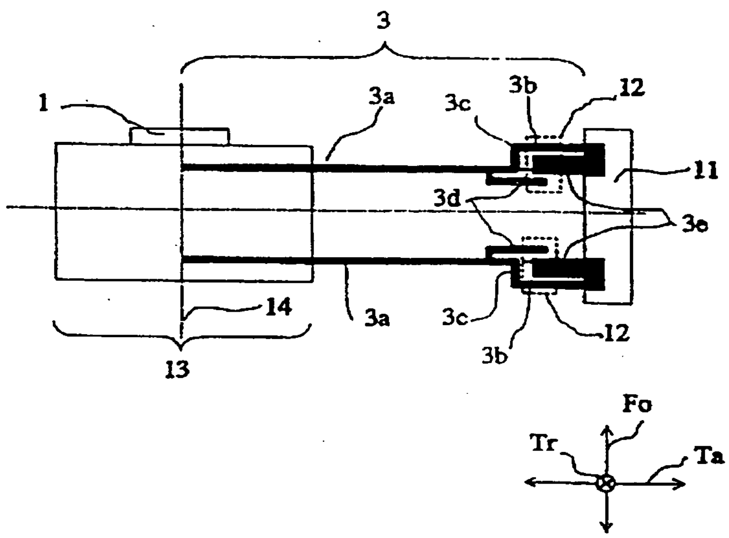
【図３０】　Fig. 30



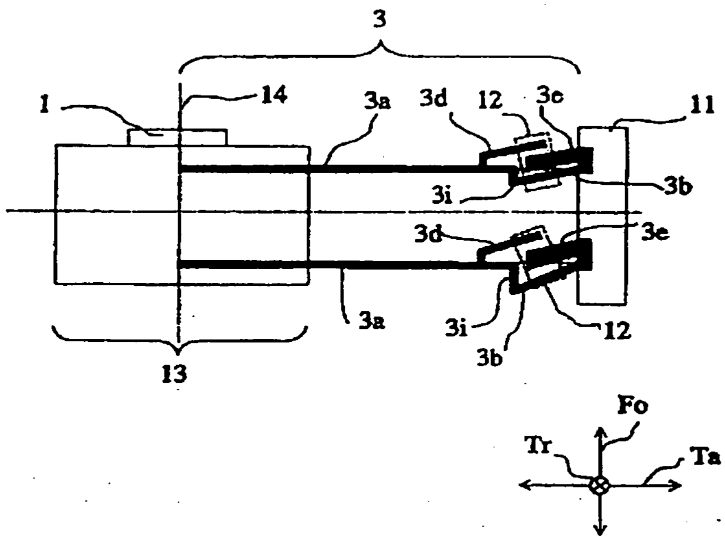
【図３１】 Fig. 31



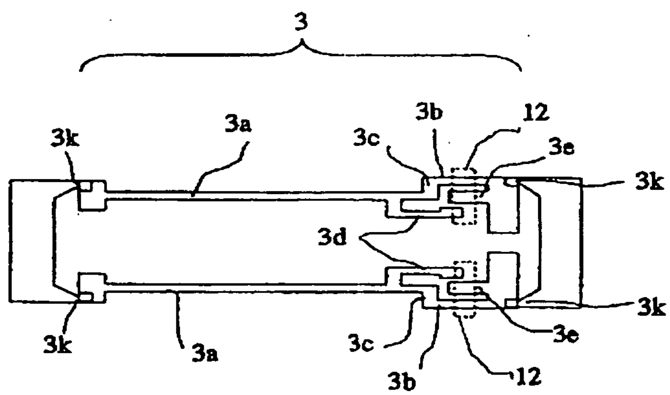
【図３２】 Fig. 32



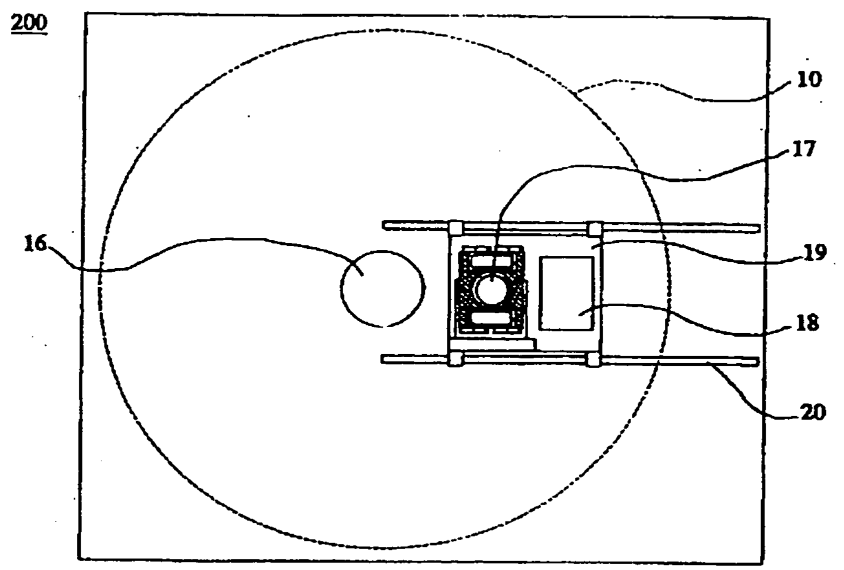
【図３３】 Fig. 33



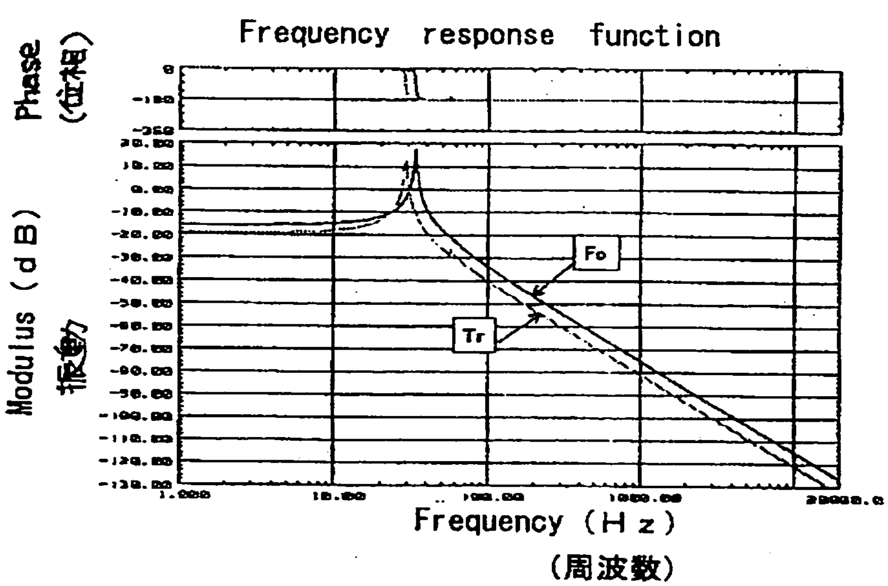
【図３４】 Fig. 34



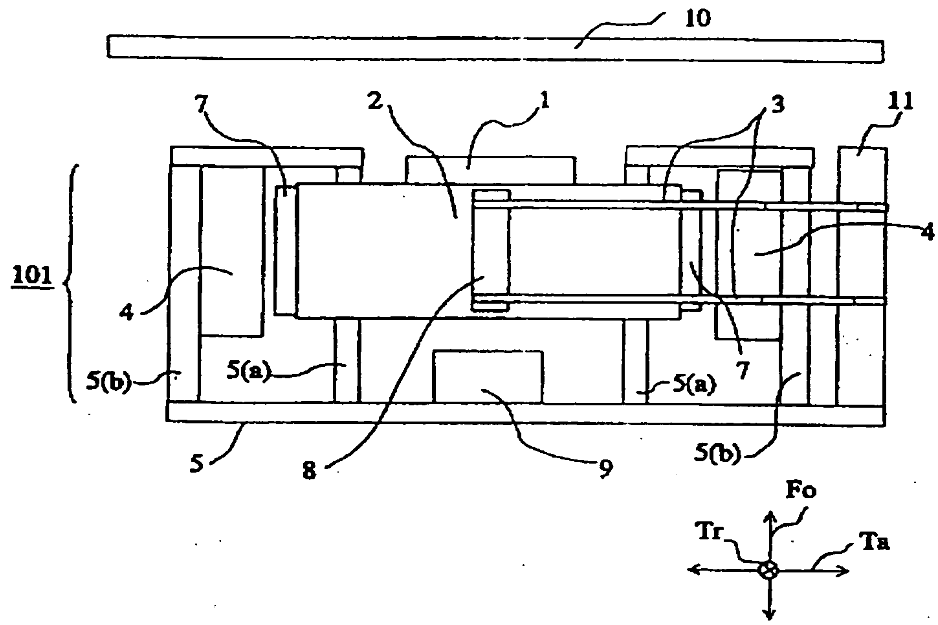
【図３５】　Fig. 35



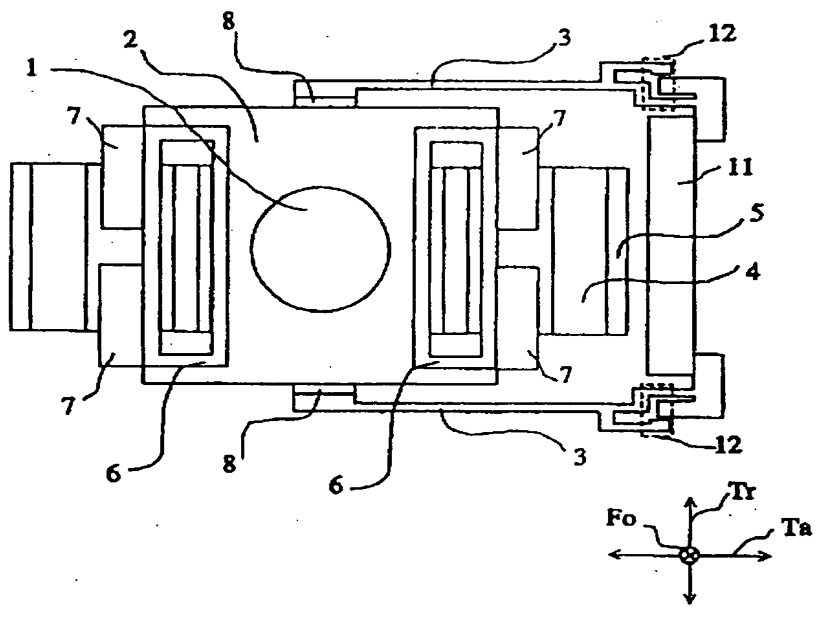
【図３６】　Fig. 36



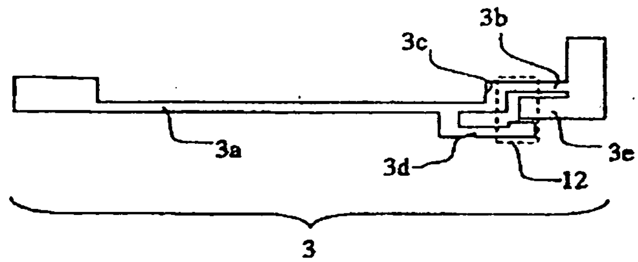
【図３７】 Fig. 37



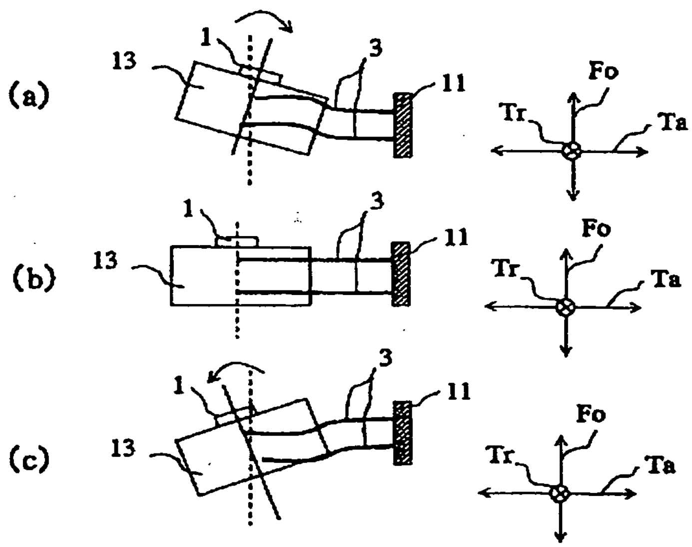
【図３８】 Fig. 38



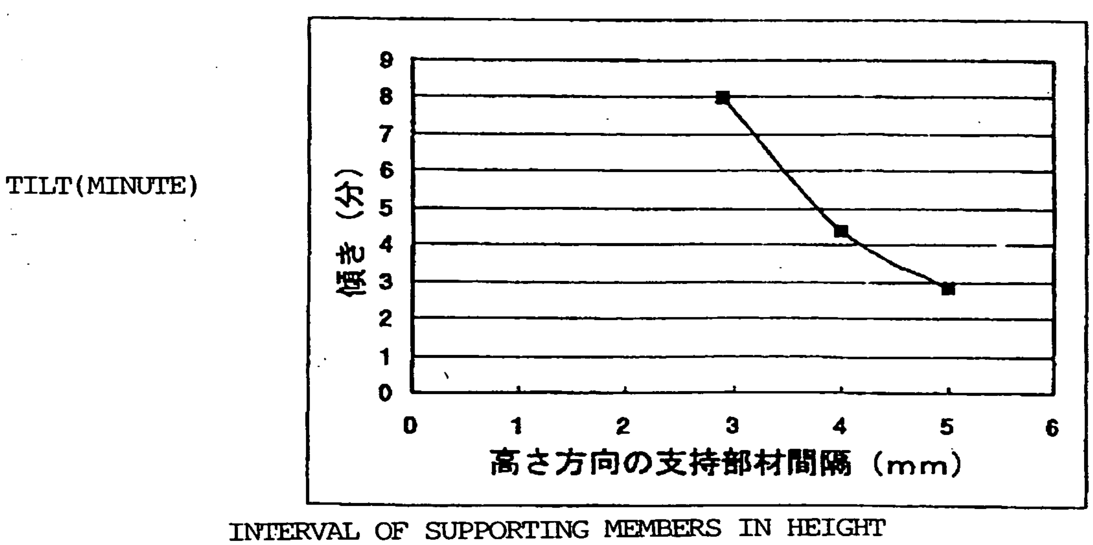
【図３９】　Fig. 39



【図４０】　Fig. 40



【図４１】　Fig. 41



[Document Name] Abstract

[Abstract]

[Subject] A tilt correction method of a movable portion, a tilt correction method of an objective lens for an optical disk, and an objective lens driving device for an optical disk can be provided capable of reducing the size of the movable portion, minimizing tilt of the objective lens in the focus direction to provide enhanced optical performance, and restraining a resonance peak by elastic supporting members.

[Solving Means] A plurality of elastic supporting members 3 supporting an objective lens 1 have bent portions 3c bent approximately in the focus direction and are arranged in parallel approximately in the focus direction to cause expansion/contraction of the elastic supporting members 3 in the direction offsetting a moment M.

[Selected Drawing] Fig. 5

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